Research and Goal Priorities for Fish Habitat Management: Science Support Requirements for Implementing the Fish Habitat Protection Provisions of the *Fisheries Act*

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RESEARCH AND GOAL PRIORITIES FOR FISH HABITAT MANAGEMENT: SCIENCE SUPPORT REQUIREMENTS FOR IMPLEMENTING THE FISH HABITAT PROTECTION PROVISIONS OF THE *FISHERIES ACT*

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ABSTRACT

Research questions and knowledge gaps of Fisheries and Oceans Canada Fish Habitat Management (FHM) were identified through a series of workshops and interviews held with FHM biologists and managers from the Central and Arctic Region over the period 1996 to 2005. Many areas were identified where scientific investigations are required to facilitate consistent application of the Policy for the Management of Fish Habitat. A short list of science priorities was developed by the Regional Habitat Coordinating Committee for FHM in the Central and Arctic Region. The need for FHM to work with Fisheries and Oceans Science to develop scientifically defensible, hypothesis driven, data collection and monitoring programs was identified as a key priority. Periodic updating of this document, as research goals and priorities are re-assessed, is recommended.

RÉSUMÉ

On a identifié les questions et les lacunes de l'étude de la Gestion de l'habitat du poisson (GHP) de Pêches et Océans Canada à partir d'une série d'ateliers et d'entrevues tenues auprès de biologistes et des gestionnaires de la région du Centre et de l'Arctique entre 1996 et 2005. On a détecté de nombreux secteurs où des enquêtes scientifiques étaient nécessaires pour faciliter l'application uniforme de la politique sur la gestion de l'habitat du poisson. Une liste brève des priorités scientifiques a été élaborée par le comité de coordination de l'habitat régional pour le GHP dans la région du Centre et de l'Arctique. On a identifié comme priorité principale la nécessité pour la GHP de travailler en collaboration avec le secteur des sciences de Pêches et Océans afin d'élaborer une collecte de données scientifiquement justifiable et fondée sur des hypothèses et des programmes de surveillance. On a recommandé la mise à jour périodique du présent document, au fur et à mesure que les buts et priorités sont soumis à une nouvelle évaluation.

1.0 INTRODUCTION

The scientific accountability of Fisheries and Oceans Canada Fish Habitat Management (FHM) decisions relies on a strong link between fish management biologists and fish habitat researchers. This document strengthens this link by identifying, for Fisheries and Oceans Canada Science (DFO-Science), FHM research needs required to support effective and defensible decisions with regard to works or undertakings affecting fishes or fish habitat.

This report builds on several past efforts devoted to determining critical research needs and priorities for DFO-Science undertakings in support of FHM. It is anticipated that it reflects general agreement on current science needs in support of FHM operations that will enable FHM staff in all four Areas of the Central and Arctic Region (Ontario-Great Lakes, Prairies, Western Arctic, and Nunavut) to render informed decisions in the day-to-day application of the habitat protection provisions of the *Fisheries Act*. Efforts have been made to identify the various workshops and reports that provide the basis for the recommended priorities outlined in this report. Because the needs and priorities of FHM staff will change, this document is intended to provide an open-ended link between FHM and DFO-Science and to create a foundation for future collaboration. Periodic updating of this document as research goals and priorities are reassessed will ensure it remains relevant to both DFO-Science and FHM practitioners. This document is intended to provide the basis of building and improving on the Regional Science and FHM programs.

1.1 BACKGROUND

The Policy for the Management of Fish Habitat (DFO 1986) provides guidance to fish habitat managers on the administration of the habitat protection provisions of the *Fisheries Act* in a manner that results in no net loss (NNL) of the productive capacity of fish habitats, with the objective of net gain of productive fish habitat. However, implementation of the policy has necessarily preceded the provision of a foundation of solid scientific research upon which habitat managers could draw. Consequently, a variety of approaches to interpreting the best methods to achieve NNL of productive capacity were applied. The result has been that decisions on the mitigation or compensation required for a site, and the monitoring efforts to determine whether there has been a change in the productive capacity, are often more qualitative than quantitative, and have frequently been inconsistent between area and regional offices.

The measurement of productive capacity of an ecosystem is a difficult goal. The 1987 workshop in Nanaimo (Levings et al. 1989) concluded that the measurement of productive capacity, defined as "the quantification of relationships between habitat features and fish production", remains "the most important and most difficult aspect of FHM". Subsequent meetings (Burlington, ON 1988; Halifax, NS 1990; and Canberra, Australia 1993) reached similar conclusions. This led to a National Headquarters policy directive to fish habitat managers in 1995 stating that the use of surrogates for productive capacity was appropriate where: "the effects of a project on the physical,

chemical, and biological components of fish habitat will normally be assessed as surrogates for impacts to productive capacity".

A similar process was simultaneously occurring in the United States. The Habitat Research Plan (HRP) of the U.S. National Marine Fisheries Service identified five key areas for fish habitat research (Thayer et al. 1996):

- ecosystem structure and function
- effects of habitat alteration
- habitat restoration methods
- impact and recovery indicators
- synthesis and information transfer

Based on these five research areas of the HRP, Fisheries and Oceans Canada National Coordinating Committee for the Environmental Science Program convened a workshop in Sidney, BC (Levings et al. 1997) to explore methods to improve the assessment of productive capacity. This workshop, as well as several subsequent workshops working towards the same goals, is briefly described in Section 2.0.

1.2 OBJECTIVES

The objectives of this report are to outline, for use by DFO-Science and other habitat researchers, the research needs and knowledge gaps of FHM. Actions and roles necessary to address the challenges are also identified. Proceedings from various workshops have discussed, and sometimes prioritized, various research questions and knowledge gaps of concern to FHM. However, progress towards getting the answers to these questions on-hand for day-to-day use by fish habitat managers has been slow. To this end, this report addresses both those asking the questions as well as those tasked with solving them. Recommendations from Fish Habitat and DFO-Science staff towards the dissemination of the best available science are also included.

2.0 PARTICIPATORY PROCESS

Several workshops and other participatory forums have been held within the Central and Arctic Region with the goal of working towards a national consistency in the application of the Policy for the Management of Fish Habitat. Knowledge gaps, which need to be resolved in order to reach this goal, were identified. These FHM and DFO-Science workshops, reports, and discussions are briefly described below:

2.1 FHM WORKSHOPS

Sidney BC 1996: DFO Workshop on Research Priorities to Improve Methods for Assessing Productive Capacity for FHM and Impact Assessment (Levings et al. 1997)

Three goals led to the instigation of the 1996 DFO Workshop:

- Compare methods in use across the country to measure changes in the productive capacity of fish habitats.
- Determine the shortcomings of these with respect to science and operational perspectives.
- Reach a consensus on research priorities and research direction.

Workshop participants were given the option of using the Habitat Research Plan of the United States (Thayer et al. 1996) as a framework.

Discussions were held on the role that basic science should have in broadening understanding of the functioning of aquatic ecosystems in order to provide a basis for attaining no net loss of productive capacity. Ten key areas of interest were identified and are ranked below:

1) extension and technology transfer between Science and Management
2) measurement of productive capacity
3) mitigation, restoration, and compensation techniques
4) ecosystem research
5) technology for habitat characterization
6) modeling of productive capacity and advancing understanding of the concept
7) habitat mapping
8) research on habitat alterations
9) retrospective analyses
10) risk analyses

The overriding conclusion of the workshop was that there is a need for a broad-based program of ecosystem research with a focus on methods of measuring productive capacity.

Barrie ON 1997: Science for Fish Habitat Management Workshop (Lester et al. 1997)
This workshop brought together members of Canadian provincial natural resource agencies along with federal fish habitat managers. The topics of this workshop were categorized into either impact assessment and prediction needs, or data collection and inventory requirements.

A list of science needs prepared by the impact assessment and prediction group included mitigation and compensation techniques and their efficacy, as well as the effects of various projects such as shoreline protection works, water level fluctuation, and road construction, on fish habitat. Inventory requirements were discussed in terms of the scale of habitat concerned as well as the reason for the inventory. It was decided that inventories conducted for resource management should focus on ecological functions and be as simple as possible; whereas those conducted for scientific research need to have an explicit purpose in order to target all appropriate variables. Resource management inventories typically occur at a much larger scale than scientific research inventories, which tend to focus on parameters relating only to the particular question.

Regional inventories may be required to understand key ecosystem components that can influence management plans.

Hecla Island MB 1998: Prairie Fish Habitat Management Workshop (Chang-Kue 2000)

In 1998, a workshop involving federal and provincial Prairies fisheries personnel and managers was held at Gull Harbour (Hecla Island), Manitoba. Participants were tasked to develop action plans addressing 14 current and forthcoming habitat issue topics in separate discussion groups. After evaluating management objectives and identifying potential knowledge gaps, barriers, or opportunities for each topic, several recommendations relating to science research and habitat management emerged. They are summarized as follows:

- There is a need to assess compensatory measures that are presently in use. This should be addressed through integration of DFO-Science and FHM policies and priorities.
- Scientifically defensible methods are needed for assessing the productivity loss associated with whole lake destruction. This should be addressed via specific research projects focused on aspects of productivity loss associated with whole lake destruction.
- There is a need for research into micro/macro (scale dependent) and synergistic effects that are tied to cumulative effects. The development of quantitative measurement guidelines detailing methods to follow when undertaking cumulative effects assessments was suggested. Guidelines delineating acceptable changes to habitats should be developed.
- There is a need to develop a scientifically defensible basis for the determination of setback distances for timber harvesting next to waterbodies. Regional guidelines should be developed in this regard.
- Regional multi-disciplinary instream flow needs (IFN) oriented research is needed to delineate needs for various species.
- Clarify the links from flow to habitat to biomass.
- Establish Instream Flow Needs Working Group for the Region in order to establish common goals and provide direction for research.
- Establish Prairie Provinces/DFO-Science agreement to promote collaborative science.
- There is a need for research on species upstream and downstream of hydro dams in order to assess species flow needs and the effects of hydro peaking. Develop research tools to accurately gauge peaking hydraulics.
- Need to collate and update existing agricultural guidelines to provide dedicated guidelines for specific agricultural practices that eliminate redundancy and identify gaps.
- Research is needed to broaden understanding of the impacts of channelization on fish and fish habitat to provide a basis of support for approaches that are implemented.
- Need research to provide science-based guidelines in support of acceptable practices for aggregate extraction to ensure no net loss.

- Need science-based guidelines relating to wild rice to ensure no net loss is associated with the production of wild rice. Need research to acquire a better understanding of the effects of wild rice on aquatic ecosystems.

All Staff ON 2000: Priority Setting for Ontario-Great Lakes Area (Gomes Consulting Enterprises, 2216 Ridge Landing, Oakville, Ontario, L6M 3L7 2001, unpublished data)
At this meeting, Ontario-Great Lakes Area (OGLA) staff was asked to identify gaps in scientific knowledge, determine sources of information for work already conducted, prioritize issues, and develop research questions. Five main topics were discussed with respect to the above goals:

- assessment tools to quantify mitigation and compensation requirements
- physical habitat alteration
- buffer zones and compensation/mitigation measures
- human-made structures
- surface/groundwater hydrology and barriers

In total, 29 priority research issues were identified, including fifteen high, eight medium, and six low priority issues. A gap analysis was recommended to determine which, if any, of these issues was being investigated, and what work has already been done. The intention of the gap analysis was to increase the accessibility of completed information to staff biologists.

Gimli MB 2001: Perceived Science Needs of FHM
In March 2001, a workshop was held in Gimli, Manitoba, in order for FHM and provincial fisheries personnel to exchange ideas about science research needed to support FHM.

Emphasis was placed on the need for guidelines, protocols, monitoring standards, and models to be scientifically defensible. The primary FHM needs were identified as:

- literature reviews of scientific studies
- synthesis of scientific information
- 'Pathways of Effects' research
- research on the effectiveness of mitigation techniques
- development of a clear understanding of scientific gaps
- monitoring

The priority research areas where FHM needs defensible scientific information were identified as follows:

1) Effectiveness of compensation and mitigation measures to alleviate habitat alteration, disruption, or destruction (HADD).
    - Many of the techniques currently in use have not been tested scientifically to see if they are effective.

2) Development of quantitative assessment tools to determine IFN in streams and rivers.

3) Development of defensible methods for quantifying habitat productivity.
   - This is needed to meet the Policy for the Management of Fish Habitat guidelines for productive capacity.

4) The impact of physical alterations on productivity: FHM needs up-to-date guidelines for:
   - macrophyte removal
   - deep water wood removal
   - wild rice production vs. productivity

5) Determination of cumulative impacts.
   - This is a Canadian Environmental Assessment Agency requirement that may become part of HADD
   - Cumulative impact assessment is also important to prevent a net loss of the productive capacity of fish habitat.

6) Development of riparian plantings and buffer zone guidelines.

Dorset ON 2001: Design Standards for Improving Fish Habitat Management Workshop (Gillespie et al. 2002)

The purpose of this workshop was to develop scientific design standards for assessing the effectiveness of fish habitat mitigation and compensation measures. Participants included scientists, managers, and consultants from a variety of disciplines ranging from statistics and experimental design to engineering, habitat management, and fish biology. The primary goal of this workshop was to develop cause-effect pathways for key issues so that habitat change can be quantified with ecological indicators. Generic study designs were developed using the hypothesis-of-effects (HoE) diagram methodology. This methodology explores physical, chemical, and biological processes in terms of their linkages across spatial and temporal scales and can help identify critical areas where development activities lead to impacts on fish habitat. Mitigation and compensation measures can be used to avoid, reduce, or offset harmful impacts. In order to explore HoE diagrams and determine integrated experimental designs to test outcomes of mitigation and compensation, this workshop was limited to discussion of habitat change associated with culverts, stream realignments, and shoreline stabilization.

2.2 SCIENCE WORKSHOPS

Ottawa ON 2003: Science Technology Transfer Workshop– Science Contributions Toward Improving Fish Habitat Management (DFO 2004)

This workshop brought together Science and Fish Habitat personnel from across the nation to discuss recent DFO-Science research related to FHM. This workshop

explored means by which future research could be tailored to address the information needs of FHM. Four main areas of research were discussed:

- measuring habitat productive capacity
- threshold response to habitat alteration
- effectiveness of compensation
- managing risk and uncertainty

Investigation into the habitat-dependent process rates of fish populations was identified as a longer-term priority for DFO-Science towards measuring the productive capacity of a habitat. As knowledge grows, this research is expected to benefit both site-scale, and broad-scale management questions. Primary to this research is the need to identify self-sustaining fish community targets and to set benchmarks of productive capacity against which changes to habitat can be assessed. Because the response of fish populations to habitat change is frequently non-linear, an understanding of thresholds at a watershed and a population scale is needed.

In the meantime, DFO-Science can help FHM develop broad-scale tools that will aid in the evaluation of habitat capacity at the site level. One such tool is the determination and mapping of habitat productive capacity for large areas in order to develop regional Fish Habitat Management Plans, as is presently occurring in the Great Lakes. Because of their application over large spatial scales, these are necessarily first-order determinations of habitat capacity.

It was acknowledged that despite significant effort on the part of habitat managers, net loss of productive habitat was occurring. Decreasing uncertainty about compensation ratios may solve some of this problem. Implementing standardized methods for monitoring fish response to habitat changes will strengthen the results obtained, thus enabling an adaptive management approach to be taken towards understanding appropriate compensation ratios. In order to facilitate information sharing, it was agreed that the results of habitat science research should be disseminated in the form of Canadian Science Advisory Secretariat Research Documents and Advisory Documents.

Gray Rocks QC 2004: Science Review Workshop (Sussex Circle Inc., 50 O'Connor Street, Suite 1424, Ottawa ON, K1P 6L2, unpublished data)
This meeting of DFO-Science sector was convened in order "to identify concrete actions that can be implemented to ensure the long-term sustainability and relevance of the Science program" with the goal of developing a new implementation plan. One focus of the Science program is to support departmental policies such as the implementation of the *Fisheries Act*. The main discussion points from the workshop were:

- The application of the *Species at Risk Act* (*SARA*) will impose significant demands on Science. Expect major increases in ecosystem-level data requirements.
- Science reform may be able to incorporate, for example, a new emphasis on sustainable development within the context of research questions regarding the *Fisheries Act* and habitat policy.

- Science needs to be aware of emerging issues and plan for appropriate baseline data and science capacity to respond.
- Some concerns were raised about data management in conjunction with monitoring efforts. Suggestion was to provide national methodology, standards, protocols, and technologies.
- Coordination of Science efforts stemming from a Virtual Centres of Expertise (VCE) model might help to address more specialized regional/ecozonal science needs.
- An Environmental Science Strategic Research Fund (ESSRF) model may be useful to establishing science priorities.
- A key recommendation was for DFO-Science to consider areas of high risk and high science impact and look ahead 5-10 years when prioritizing research.

2.3 REPORTS AND DISCUSSIONS

Fisheries Science Activities in the Prairie Provinces

In May 1998, DFO signed a Memorandum of Understanding (MOU) with Manitoba, Saskatchewan, and Alberta on prioritizing fisheries science activities in the Prairie provinces. In September 2001, the federal (DFO and Environment Canada) and Prairie provinces' Fisheries Ministers announced a revised MOU that included improving collaboration and cooperation. Presented with funding pressures for freshwater research, the Ministers agreed that, where possible, science priorities should be coordinated to ensure delivery of the most effective science programs in each jurisdiction. A Federal-Prairie Provinces Fisheries Science Team was tasked to identify common fisheries science needs and priorities relating to, amongst others, habitat productivity; physical habitat alteration, destruction, and remediation; and chemicals in the environment. The deliverables expected from the team included:

- Identify and report on common provincial and federal fisheries science needs within the Prairie provinces.
- Establish priority-setting criteria and establish joint priorities.
- Identify potential federal and provincial internal and external funding mechanisms for program implementation and prepare a plan to undertake priority science projects.
- Develop a review and evaluation process for the agreed program.
- Continue with collaborative research projects.
- Prepare an annual progress report to the Directors.

Report from the Eastern Arctic Area Habitat Team 2004

Discussions with the fish habitat staff from the Eastern Arctic highlighted the following areas of concern:

- loss of whole lake systems
- productivity of inter-tidal areas
- geomorphologic response of northern streams/rivers to changes in sediment load, flows, etc.
- habitat requirements of *SARA* species in the Arctic

Regional FHM Activities

In the fall of 2002, Regional Fish Habitat Managers identified the following priority areas for strategic research in support of FHM:

- offshore oil and gas
- productive capacity
- fish/land use interactions
- instream flows for fish (methodology development)
- compensation and mitigation
- mobile fishing gear impacts
- aquaculture
- ecosystem-based management
- exotic species issues
- hydroelectric development and reservoir creation
- pesticides
- sediments

This list of priorities was reduced to four high priorities in 2003:

1) No Net Loss
   - science-based tools for consistent decision making
   - research on quantification of productive capacity
   - compensation methodology and effectiveness assessment
   - mitigation and HADD determination
2) Whole Lake Destruction and Compensation
   - Research on developments at the watershed level is needed to increase understanding of valued ecosystem components, productivity, and how effectiveness of compensation can be measured. Diamond mining will be the focus but results will be more broadly applicable.
   - cumulative effects
3) Offshore Oil and Gas, Aquaculture
   - FHM needs ocean bottom mapping and peer-reviewed scientific advice on HADD avoidance.
   - marine compensation for HADDs, dealing with potentially deleterious deposits
4) Instream Flows and Hydro
   - FHM requires research on minimum flow requirements in dealing with water withdrawals and the impacts of hydroelectric development.

Regional Management Committee Meeting January 2003

The Regional Management Committee met in January 2003 to review science initiatives and to develop, through a 'Science Futures' exercise, a plan to prepare for potential freshwater fisheries and marine fisheries science needs by 2020. Science needs of FHM need to be taken into consideration in the Science Futures exercise so that, where

feasible, consideration of priorities and the possibility of cooperative ventures are factored into long-term science planning.

Open communication is needed in order to develop mutually beneficial research partnerships that address the science needs of FHM. In ensuing years, the success of the FHM program will, to a large extent, hinge upon broadening cooperation with research scientists to ensure that advice and recommendations are science-based and defensible in court. Science managers need to align the attributes of their staff in a manner that encourages cooperative work between DFO-Science and FHM.

As gaps in understanding relating to implementation of the FHM program become apparent, there will be an ongoing need to revisit the list of Science Priorities and refocus resources in a timely manner.

3.0 RESEARCH REQUIREMENTS OF FHM

One of the primary goals of FHM is to make decisions that are scientifically defensible in court on a site-by-site, case-by-case basis that result in no net loss in the productive capacity of fish habitat (DFO 1986). Habitat Conservation and Protection Guidelines (DFO 1998) define productive capacity as "the measure of the capability of a habitat to produce fish and/or food organisms in natural or restored conditions". Productive capacity is further defined as being the "maximum number of organisms that can be sustained on a long-term basis by a given habitat". Thus, a single measure of fish biomass for a habitat may not be indicative of that habitat's long-term productive capacity. Because it is often difficult to measure the potential productive capacity of sites, generalizations about the productive capacity, which can be constructed from determining habitat type and habitat volume, are frequently used as surrogate measures of productive capacity.

Coupled with the need to understand how to quantify the productive capacity is the need to quantify the effectiveness of mitigation and compensation measures on maintaining or increasing the productive capacity of the habitat. A major difficulty for fish habitat managers is that the effects of mitigation and compensation in the context of project alterations have not been fully examined to determine their effectiveness relative to the original condition of the site.

Through the information gathering process for this report, various knowledge gaps and science needs were identified. All questions and comments have been included in this report and have been grouped into four research needs: productive capacity (Section 3.1), fish research (Section 3.2), fish habitat (Section 3.3), and management tools (Section 3.4). For each section, research questions are prioritized in a table based on priority assessments done through workshops and interviews.

These research questions are a compilation of many workshops, discussions, and interviews, and many have been given an absolute priority (high, medium, low), but have not been ranked against each other. They have been clustered not only by topic

and priority (when available), but also by their scale and broadness of inquiry. This should facilitate their ranking during subsequent discussions on research goals and direction. It is recommended that these lists be revisited when short and long-term research plans are being drafted.

3.1 PRODUCTIVE CAPACITY

This section includes questions regarding the definition and measurement of productive habitat and how to prevent its loss, as well as understanding the cumulative effects of multiple or large scale projects. Fish habitat managers identified many knowledge gaps which hinder their ability to make defensible, consistent decisions across both a wide variety of project referrals and for a large variety of habitat types. A principal concern was the lack of analytical tools available to: a) predict how much the productive capacity of a habitat would change due to a project impact; and, b) quantify the compensation required to prevent a net loss in productive capacity. Central to this concern was the question of how to quantify productive capacity in any and all habitats. Other knowledge gaps relating to the productive capacity of habitats were concerned with the natural variability of habitats, the impact of a project on the habitat, and the compensation required to prevent net loss of productive capacity. These topics are discussed below and are presented as a prioritized list in Table 1. Priorities listed in the table were assigned during workshops and therefore some may be historical in nature.

Defining and Measuring Productive Capacity

Rather than give specific minimum stock biomass for each habitat type, DFO chose to encompass the ecosystem approach in defining the productive capacity of a habitat as its natural (or restored) ability to produce fishes and/or food organisms that sustain fishes. Thus, chemical, physical, and biological surrogates are currently used to estimate the potential impact of a project on the productive capacity of a habitat. In the Great Lakes, Minns' defensible methods approach takes both physical (current direction, substrate) and biological (habitat suitability indices based on life history requirements) features of a habitat to predict the potential impact of a project on the local productive capacity (Minns and Nairn 1999, Minns et al. 1995, 2001). In rivers, natural channel design is often incorporated into project construction plans in order to preserve (or restore) the physical, chemical, and biological self-organizing properties found in undisturbed rivers.

The primary question is whether these approaches are working to prevent a net loss of productive capacity over time. Several examples were raised at the workshops where loss occurred despite planning efforts to the contrary. Some of the observed loss of productive capacity was found to be due to a low compliance level on the part of the proponent, and some was due to compensation measures operating less effectively than anticipated. Several questions and ideas were put forward that would help to examine this topic:

- How can the productive capacity of streams be measured?
- Do constructed structures increase or re-distribute productivity?

- What observations from past projects can be incorporated into future projects?
- What monitoring efforts can be standardized to effectively measure success of mitigation and compensation used in projects?

Understanding Natural Variability of Productive Capacity

The productive capacity of habitat is temporally variable and dependent on many local and watershed scale characteristics. Natural controls on productive capacity include biodiversity, invasive species, food supply, and nutrient loading. Productive capacity is also dependent on seasonal and yearly fluctuations and can vary depending on local and regional weather conditions. Questions under this topic may tie in with other issues because of their broad nature.

Throughout various workshops, several topics were identified as high priority. They included the role of biodiversity in maintaining productive capacity; assessing the importance of wetlands, intermittent watercourses, and intertidal areas; and understanding how habitat heterogeneity affects fish community abundance and distribution. Two of the most common concerns identified were: 1) a need to understand the effect of various buffer widths surrounding aquatic habitat; and, 2) a need to determine minimum (base) flow requirements to sustain fish communities.

These questions are challenging. The response of a fish community to changes in habitat is frequently non-linear. Natural communities are often quite resilient to changes; therefore, it may be that no response is noticed until a threshold condition is reached, at which point there may be a significant drop in productive capacity of that fish community. It is likely that these questions will need to be addressed using long term studies.

Quantifying Anthropogenic Impacts on Productive Capacity of Habitats

Fundamental to the work of FHM is the need to understand if and when an impact is likely to cause a HADD of fish habitat. Equally important is the need to be able to estimate quantitatively what the effects of that impact are likely to be to the productive capacity of the habitat, both on- and off-site.

Proposed works (referrals) can affect directly and indirectly many aspects of the aquatic environment. Effects on habitat structure can range from small shoreline works to whole lake destruction. Changes in land use surrounding the aquatic habitat can have long-term effects on food web processes, rates and productivity, water temperatures, and hydrology. Direct effects include water withdrawals and cage aquaculture.

Typical projects encountered by FHM staff include:

- wetland protection/restoration
- peat extraction
- lake/reservoir destruction
- shoreline alteration/protection
- aquaculture (cage)
- water withdrawal and water level fluctuations

- road, culvert, and pipeline installation
- hydroelectric facility and dam construction and removal
- woody debris/beaver dam removal
- dredging of lakes and streams, side-casting
- agricultural drain cleanout
- land development (agricultural, suburban)
- mining operations
- heat loops
- submarine cables

The dominant question fish habitat managers asked with respect to the above types of works concerned the effects or impacts of the activity on fish production or the productive capacity of the habitat, and how can the activity be adequately compensated.

The topic of whole lake destruction particularly highlights the challenges of fish habitat biologists. This type of work has occurred in areas where finding adequate compensation sites were challenging because of the remoteness of the locations.

Fish habitat managers need tools to enable them to predict and quantify how these changes may affect habitat quality and quantity. The development of these tools began with the Habitat Alteration Assessment Tool (HAAT), also known as Minns' Defensible Methods for shoreline works in the Great Lakes (Minns and Nairn 1999, Minns et al. 1995, 2001). Tools for use in streams and wetlands are still lacking.

Preventing Net Loss of Productive Capacity through Compensation

Compensation for the HADD of fish habitat is officially the least preferred method used to prevent an overall net loss of productive habitat. Due to the higher risk associated with compensating for a HADD rather than preventing a HADD, this option is only available after project relocation, redesign, and mitigation have been considered. Nevertheless, compensation plans are a large component of authorizations under the *Fisheries Act*.

Work causing the loss of habitat within degraded areas will need to compensate for the potential productive capacity of that habitat, rather than its current degraded capacity. This recognizes that the loss of this particular habitat means the loss of the potential to restore it to its original productive capacity.

Several studies on FHM referral projects have found a net loss of fish productivity despite compensation efforts (Harper and Quigley 2004; Bowman et al. (Jennifer Bowman, Fisheries and Oceans Canada, Great Lakes Laboratory for Fisheries and Aquatic Sciences, 867 Lakeshore Road, Burlington, ON L7R 4A6, unpublished data); Golder Associates, 2390 Argentia Road, Mississauga, Ontario, L5N 5Z7, unpublished data). It is very important to pursue research on quantifying appropriate compensation for the HADD of fish habitat.

Specific questions were raised regarding compensation related to the functioning of riparian plantings, wetland creation or restoration, the creation of new habitat through wood additions or shoal creation, and the use of natural stream channel design when creating new stream habitat. Another question raised was how to account for the replacement of one type of habitat (e.g., river) with another (e.g., lake). It was agreed that tools such as HAAT, which is best suited for large lakes, should be created for more habitat types in order to increase the accountability of the FHM program. This should be given top priority.

Table 1. Knowledge Gaps and Research Needs Concerning Productive Capacity of Fish Habitat

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Defining and Measuring Productive Capacity		
	• Define surrogate measures that can be used to quantify productive capacity in each habitat type.	high
	• Are different surrogate measures of productive capacity needed in pristine versus degraded systems?	high
	• What is the functional relationship between habitat and fish production?	high
	• Does habitat creation increase or re-distribute productivity?	high
Understanding Natural Variability of Productive Capacity		
landscape processes	• How do small changes cumulate to determine large-scale effects on the watershed landscape?	high
community processes	• How does aquatic biodiversity relate to the preservation of healthy fish habitat and its productive capacity?	high
buffer widths	• Are the width requirements of riparian buffers different between rivers and lakes and do they vary with region, sediment, nutrients, temperature, allochthonous inputs, slope, and soils?	n/a
base flows	• What level of base flow is needed to support fish habitat and how does this vary depending on the region?	high
intermittent watercourses	• How do intermittent watercourses contribute to aquatic ecosystem productive capacity?	high
wetlands	• How do wetlands contribute to the productive capacity of a habitat and does this effect vary with substrate?	n/a
shorelines	• How do intertidal zones in northern climates contribute to local fisheries production?	high
woody debris	• How does woody debris contribute to fish production?	n/a
Quantifying Anthropogenic Impacts on Productive Capacity of Habitats		
timber harvesting	• What are the effects of timber harvest and clear cutting on stream fish production?	high
shoreline development	• What are the impacts of boathouses, breakwalls, and water lines on shoreline habitat?	n/a
wetlands	• What is the impact of wetland restoration works on contribution of the project site to fishery production?	n/a
peat extraction	• What are the effects of peat extraction activities on fish resources (including fish habitat)?	n/a

Table 1. Knowledge Gaps and Research Needs Concerning Productive Capacity of Fish Habitat (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Quantifying Anthropogenic Impacts on Productive Capacity of Habitats (cont'd)		
explosives	• Test if setback distances and charge size recommendations are effective.	high
drilling	• Determine impacts from off-shore drilling.	n/a
heat loops	• What are the impacts of heat exchange loops?	n/a
submarine cables	• Do submarine cables affect the aquatic environment with respect to lead, copper, oils, magnetic fields, and physical disturbance?	n/a
dams and barriers	• What are the effects of barriers to movement on fish communities, fish species, and fish habitat?	high
hydroelectric	• What are the impacts of dams and water level fluctuations on fish species (e.g., up and downstream migrants) and fish habitat (e.g., rate ramping, flood control)?	high
	• How do we incorporate the impacts of dams, hydroelectric facilities into cumulative impact assessments for other projects on the same system?	high
lake or reservoir destruction	• There is a need for a scientifically defensible method to estimate loss of productivity of the watershed with respect to whole lake destruction. How can whole lake losses be quantified and what are the critical habitat parameters that need to be measured?	high
	• How does dam removal affect fish and fish habitat both up- and down-stream?	n/a
base flows	• What are the effects of water level changes due to surface and groundwater withdrawals on fish and fish habitat, and fish spawning success?	high
water withdrawal	• What is the effect of winter water withdrawal on fish in small northern lakes?	n/a
mining	• How does mine decommissioning affect habitat?	n/a
	• How do aggregate operations affect fish and fish habitat?	high
dredging	• What are the impacts of re-suspension of sediment on fish habitat?	medium
	• What are the cumulative impacts of dredging projects, in particular during conditions of low water?	medium
	• Does side-casting material and the resulting creation of bermed or island areas increase the productive capacity of the habitat?	high
pipelines	• What are the effects of pipeline installations on habitat and instream productivity?	high
culverts and bridges	• What are the indirect and cumulative impacts from encroachment, bridges, swales, and culverts?	n/a
	• Are there any effects of ice roads?	n/a
	• Do 'Natural Stream Channel' culverts prevent a loss of habitat productive capacity?	n/a
agriculture	• What are the impacts of cover crops, feed lots, waste, cropping, tillage, etc., on fish habitat?	n/a
	• What are the cumulative effects (point and non-point sources) of multiple agricultural projects within a watershed?	high
	• What are the effects of aquaculture/fish cage culture on fish habitat?	n/a

Table 1. Knowledge Gaps and Research Needs Concerning Productive Capacity of Fish Habitat (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Quantifying Anthropogenic Impacts on Productive Capacity of Habitats (cont'd)		
drains	• What are the effects of cleaning out agricultural drains and what is appropriate compensation?	high
	• How can we maintain or increase the productive capacity of existing municipal drains that are subject to ongoing maintenance?	medium
woody debris	• What are the effects of log salvage operations and/or near-shore woody cover removal on the productive capacity of aquatic ecosystems?	low
	• What is the effect of beaver dam removal on habitat?	n/a
Preventing Net Loss of Productive Capacity through Compensation Efforts		
riparian plantings	• Do riparian plantings adequately compensate for loss of productive capacity of fish habitat?	high
aquatic plantings	• When is it appropriate to use aquatic vegetation planting as compensation?	n/a
wetlands	• How effective are wetland restoration works in increasing productive capacity?	medium
habitat structure	• What types of artificial habitat structures effectively increase the productive capacity of fish habitat?	high
	• How effective are artificial shoals for increasing productivity of various species?	medium
	• Do root wad or tree crown additions help to increase the productive capacity of fish habitat? Are they effective compensation? When do they fail?	medium
	• Are artificial spawning sites successful? How long do they last? What monitoring should be done?	low
channel design	• Does natural channel design maintain the productive capacity of the stream?	n/a
mitigation techniques	• How effective are the methodologies for mitigation/compensation that are being promoted in Operational Statements?	high
	• How can habitat transfer (change from one type to another where one type of fishery may be replaced with another type, e.g., water temperature of a lake, change from river to lake habitat) be compensated?	high
water quality	• Assessment of individual Best Management Practices (BMP) to determine if water quality is improved by them.	n/a

*n/a- not available

3.2 FISH RESEARCH

This section describes the science needed to understand the behaviour, physiology, or life history of a particular fish species or group, and how to manage larger-scale fish distribution by species or by region.

Central to understanding how habitat affects fishes is understanding how fishes use habitat. FHM staff pointed to several knowledge gaps that need attention. These questions cover a broad range of topics and include: inventories of where fishes are found, both locally and at a regional scale; life history questions regarding determination of habitat suitability indices, migration requirements, and natural egg densities; physiological research concerning swim speeds; and behavioural research focusing on

habitat use and preference. These topics are discussed below and summarised in Table 2. Priorities listed in the table were assigned during workshops and therefore some may be historical in nature.

Inventories

FHM in Ontario uses a provincial system which classifies both stream and lake habitat as either cold water habitat (trout present) or other habitat (warmwater and coolwater fish species present). Agricultural drains are currently classified according to the temperature and the types of fish species expected. Staff was concerned about whether the current agricultural drain classification system accurately depicts the true fish community. High priority was given to establishing the use of the different drain types by various fish species, and especially to identifying the seasonal variability of use by fish. This is important to determine drain clean-out schedules that minimize the effects on fishes.

Life History

Knowledge of life history characteristics and habitat preferences are crucial to developing tools to quantify the degree to which habitat loss or change affects fish productivity. One approach is to build habitat suitability indices that characterize fish habitat requirements. Habitat suitability indices (HSI) have been published for many species, particularly those that are commercially or recreationally important. For habitat suitability models from the U.S. Department of Agriculture refer to: http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm ; or, http://el.erdc.usace.army.mil/emrrp/emris/emrishelp3/list_of_habitat_suitability_index_hsi_models_pac.htm.

Life history and habitat requirements for keystone fish species found in the Central and Arctic Region need to be added to the available HSI. The transferability of these HSI to different areas within the Region also needs to be determined. Researching habitat requirements for various life stages of species at risk in the Arctic was also identified as a high priority.

Other life history questions were concerned with quantifying normal ranges of fish egg densities and distributions for many species, as well as understanding how barriers affect migration and life history requirements of warm-, cool- and coldwater species. Another important question raised was the need to identify and quantify the pattern of survival from egg to fry to juvenile to adult for various species.

Physiology

Specific questions regarding fish physiology were few, primarily encompassing questions relating to sustained and burst swimming speeds of fishes. However, identifying fish passage requirements for culverts was assigned a high priority. Of special concern was to understand passage and migration requirements for a broader variety of fish species, as well as combining swimming data with life history data to acknowledge prime migration timing in relation to hydrologic cycles.

Behaviour

Fish behaviour ultimately governs how and when fish use habitat. Fish that tend to remain in the same location will take longer to re-colonise a disturbed site than fish with a transitory or migratory behaviour pattern. A high priority question identified that recovery timing may differ between various species that reside in agricultural drains, due to differences in recolonization abilities. Incorporating fish behaviour considerations into habitat modification designs may decrease the impact of that change. This is especially important with regards to fish passage designs. Several high priority topics regarding fish passage included fish attraction, avoidance, and guidance at dams and irrigation projects, and behavioural responses to hydraulic conditions for many species and life stages of fishes. Other questions included: the effect of darkness on fish passage in long culverts, the use of artificial habitat structures, and minimum vegetation patch size usable by various fish species.

Table 2. Knowledge Gaps and Research Needs Concerning Fish Research

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Inventories		
agricultural drains	• Do drain classification methods accurately depict the true fish community and in particular fish that use drains seasonally?	high
Life History		
mitigation techniques	• Do mitigation techniques address the requirement of all life history stages (e.g., over-wintering habitat in streams)?	n/a
fish research	• Fish egg densities - information is needed to quantify fish egg density as low, medium, or high.	n/a
habitat suitability indices	• Refine HSI for keystone fish species in the Central and Arctic Region.	n/a
agricultural drains	• Does the classification system for drains take into account habitat use by various fish species (e.g., pike, suckers)?	n/a
species at risk	• What are habitat requirements for species at risk in the Arctic (e.g., freshwater fourhorn sculpin (*(Myoxocephalus quadricornis)*, Bering wolffish (*Anarhichas orientalis)*?	high
dams and barriers	• Study (or conduct literature review) impacts of barriers to migration and life histories/productivity of warm/coolwater species such as walleye/pike. What it the Impact of barriers to fish on productivity of the stream above the barrier?	n/a
Physiology		
culverts/fish passage	• Determine swimming performance for non-salmonids and larval fish. • Is the 3Q10 appropriate given the timing of spawning runs for walleye, pike and sucker, particularly in the Prairies? Are target velocities being achieved through this method?	high n/a
Behaviour		
agricultural drains	• After cleanout, what is the recovery time for various species?	high
culverts	• How long can a culvert be before darkness becomes a barrier or impediment to fish movement?	high

Table 2. Knowledge Gaps and Research Needs Concerning Fish Research (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Behaviour (cont'd)		
water level	• Examine behavioural responses to hydraulic conditions and changing water levels for various species of fish and various life stages.	high
dams and barriers	• Examine fish attraction, avoidance, and guidance at dams and irrigation project canals.	high
habitat structure design	• What are successful methods for creating new spawning sites that can be used by various fish species (walleye, etc.)?	low
	• Is there a difference in how different fish use various building materials (e.g., steel vs. cedar logs, cribbing vs. stone, etc.)?	n/a
	• What are the main functions of different types of wood structures (e.g., cover for adults, nursery habitat, etc.)?	medium
	• Are artificial groundwater upwelling areas successful in promoting fish spawning?	medium
aquatic vegetation	• Do fish show a preference for a minimum patch size or quantity (number of stems per m^2) of aquatic vegetation?	medium

*n/a- not available

3.3 HABITAT RESEARCH

Included in this section are questions that are relevant to understanding how changes in habitat affect habitat quality. These questions are important ones that ultimately influence productive capacity. They are specific to particular habitat types and may require the specialized expertise of various science disciplines. Questions were categorized into the following topics: groundwater hydrology, fluvial geomorphology, stream ecology, biogeochemistry, limnology, and habitat engineering. These topics are discussed below and summarised in Table 3. Priorities listed in the table were assigned during workshops and therefore some may be historical in nature.

Groundwater Hydrology

Groundwater hydrology deals with subsurface flows. Subsurface flows affect fish habitat as they can directly influence water supply, controlling habitat temperature and water quantities. Many activities affect subsurface flows; however their effects on fish habitat can vary depending on hydrologic connections between groundwater and surface water. A basic question raised at various workshops was how to quantify the connectivity of ground water systems (especially shallow ones) with base flow conditions in streams. Other specific questions were concerned with the impact of aggregate operations, mining, and water taking projects on base flow conditions.

Groundwater hydrology can also be used to enhance fish habitat. Groundwater upwellings provide cold, clean water into gravel beds used by many species of salmonids for spawning. It was suggested that, as compensation for the HADD, groundwater upwellings can potentially be incorporated into channel design. Several questions included how to properly plan and evaluate plans for groundwater upwellings to ensure that they are self-sustaining, with minimal maintenance requirements.

Fluvial Geomorphology

Fluvial geomorphology, specifically the interplay of surface flows and their effects on habitat, encompasses channel design, low and high flows, and sediment load. A strong interdependence exists between the physical characteristics of river systems and the quality of fish habitat. Productive capacity is directly affected by the long-term sustainability of a river channel because the physical makeup of the channel is a primary control over materials and energy distribution within a watercourse. Four high priority questions concerning fluvial geomorphology included: the impact of alterations in sediment load and physical structure on arctic permafrost dominated rivers; the prediction of sediment deposit pathways during open cut pipeline installation; the importance and contribution of headwater and intermittent streams to downstream flows; and the potential and importance of using natural stream channel design in agricultural drains. A lower priority was assigned to understanding the design and long-term sustainability of created wetlands.

Stream Ecology

Many aspects of river habitat affect its productive capacity. General questions regarding productive capacity are given in Section 3.1. However, several questions regarding streams were fairly habitat-type specific. A high priority question for stream ecology focused on the design of agricultural drains to support the habitat requirements of river fish. Additionally, it was not known how intermittent agricultural drains influence downstream fish communities, and how changes to intermittent drains will affect fish habitat. Other questions included the contribution of intermittent headwater streams to downstream fish habitat, the impact of in-river hydro facilities, and the effect of open-cut pipeline installation projects on fish habitat.

Biogeochemistry

Only one, but high priority, biogeochemistry topic came up, regarding the habitat changes associated with nutrient enrichment from sewage treatment plants.

Limnology

Several questions were raised concerning the effects of lake and shoreline habitat on fish. Apart from expanding HAAT, which is discussed in this report under Section 3.4, only two topics were given high priority. These were concerned with the effects on fish habitat productivity of aquatic vegetation removal and deepwater log removal. Wild rice production in lakes was also identified as a potentially large issue, particularly because it can entail alterations to an entire lake. Other questions included the impact on habitat of beach creation, shoreline protection projects, and dock construction.

Habitat Engineering

Habitat engineering includes the design, materials, and functional aspects of habitat alteration projects, including habitat restoration works. Questions concerning habitat engineering include the design of docks, bridge abutments, and culverts so as to provide function, as well as possibly enhance, fish habitat. Understanding how culvert designs provide passage for many species at both high and low water conditions is a high priority for FHM biologists. Preventing the input of silt into watercourses through the functioning of properly installed silt curtains and fences, the design of stormwater

management ponds, and the methods used to clean out agricultural drains was also a topic of concern. In particular, understanding buffer widths required to prevent the entry of sediment from agricultural lands was given high priority. Other questions included the effects on fish habitat of various types of materials used for construction, methods for dam decommissioning, and the impact of various hydroelectric facility designs.

Table 3. Knowledge Gaps and Research Needs Concerning Fish Habitat

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Groundwater Hydrology		
groundwater	• How are base flows controlled by connections with shallow ground water systems?	n/a
	• What are actual and cumulative impacts of activities that impact on shallow groundwater systems?	high
mining	• What are the effects of mining above and below the water table on water quality, level, and temperatures?	high
	• How does aggregate operation above and below the water table affect base flows?	n/a
upwellings	• Do artificial upwellings work and are they self-sustaining?	n/a
	• Is there a design available for self-sustaining upwellings that requires little maintenance?	medium
Fluvial Geomorphology		
arctic rivers	• What are typical channel forms in bedrock and permafrost dominated systems? How do these systems respond to changes in sediment load, flows, etc.?	high
pipeline installation	• How do typical channel forms of bedrock and permafrost dominated systems respond to changes in sediment load, flows, etc.?	n/a
	• Need sediment deposition models to predict where sediment will be deposited during pipeline installation. Short and long term effects of pipeline installation are unknown.	high
	• Assess if isolated cuts in various streams and habitat types incur more or less streambed damage than non-isolated crossings, where sediments are able to be carried downstream rather than settling on the isolated site.	n/a
intermittent watercourses	• How do intermittent watercourses contribute to downstream habitat (flow, sediment, etc.) and its productive capacity?	high
agricultural drains	• Can agricultural drains be constructed to better emulate natural channels?	high
wetlands	• What are the effects of infilling or dredging wetlands?	n/a
	• What percentage of the created wetland survives and for how long?	medium
	• What wetland creation techniques are effective to ensure the enhancement of fish habitat?	medium
Stream Ecology		
agricultural drains	• What are effective drain designs that promote drainage as well as maintain fish?	high
	• What type of compensation is appropriate for works involving alterations to intermittent drains that affect the productive capacity of the drain?	medium

Table 3. Knowledge Gaps and Research Needs Concerning Fish Habitat (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Stream Ecology (cont'd)		
base flows	• Does IFN assessment work to prevent net loss of productivity?	high
dams and barriers	• What are the impacts on fish and fish habitat associated with hydroelectric barriers, flood control barriers, carp barriers, and lamprey barriers?	n/a
hydroelectric	• What are the effects of 'run-of-the-river' hydro facilities on fish habitat and what mitigation and compensation techniques are effective to prevent a loss of productivity?	n/a
Biogeochemistry		
sewage treatment plants	• How do nutrients from sewage treatment plants affect fish and fish habitat, and can these effects be compensated? (Ontario Ministry of the Environment and Energy should be involved in this question.)	high
Limnology		
aquatic vegetation	• What are the effects on habitat productive capacity associated with removal of emergent/ submergent vegetation? Are there areas or substrates where vegetation is more valuable? What is the 'critical limiting' habitat?	high
	• How much aquatic vegetation can be removed from eutrophic (prairie) lake systems before HADD occurs?	n/a
	• How does fragmenting or 'cookie cutting' a weed bed or cattail mat affect habitat productivity?	n/a
	• Do artificial channels cut through dense cattails/peat bogs/mats increase the productive capacity of fish habitat? For how long?	medium
wood removal	• Does the removal of naturally occurring woody debris from littoral areas differ from the removal of artificial debris (e.g., scrap wood)?	low
	• What is the impact on fish habitat when deepwater scrap timber material (resident for many years) is removed? Is this removal any different than the removal of littoral woody debris?	high
	• Is 5 m (or 10 m as given in the Operational Statement for log salvage) appropriate for determining shallow versus deep?	high
	• What impacts on water quality result from log removal in terms of sediment disturbance, DO, and water chemistry?	high
wild rice	• What are the positive and negative impacts of introduced wild rice on the aquatic ecosystem especially with respect to fish habitat?	high
beach creation	• What are the impacts of beach creation on habitat?	n/a
shoreline protection	• Do some designs work better than others for increasing the productive capacity along with providing shoreline protection?	n/a
	• When do incremental shoreline alterations become measurable with respect to filling, loss of shallow water habitat, impacts of dock, boathouses, breakwaters, shoreline currents?	n/a
docks	• Should there be a size restriction on the surface area of decking used for docks and boathouses? Should this vary with substrate type?	low
	• Is there a size limitation - substrate interaction for various types of dock designs?	low
	• Are floating docks and pole/pipe docks harmful to fish and fish habitat?	high

Table 3. Knowledge Gaps and Research Needs Concerning Fish Habitat (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Habitat Engineering		
docks	• How should docks/steel walls be designed to maximize fish habitat as well as maintaining their function?	low
	• What are the best designs to minimize impacts of waves and ice on a structure/boat that improves fish habitat?	n/a
culverts and bridges	• Does the PEI bridge abutment design improve fish habitat? Would this design function similarly in freshwater?	n/a
	• What are effective techniques that can be used in culverts to ensure fish passage?	high
	• How can erosion problems resulting from improper culvert positioning be remediated?	medium
	• What designs minimize road sediment washing into fish habitat?	n/a
	• What are the impacts of primary, secondary and tertiary road development? How do abandoned roads affect fish habitat as the roadbeds decay?	n/a
	• Are requirements for fish screens on intakes used when building ice roads/bridges effective?	n/a
	• How should causeways and low level crossings be designed, positioned, and used in order to avoid impacts to riparian vegetation and fish habitat from potential water damming, erosion, input of manure from farm vehicles, and their potential to block fish migration?	low
silt containment	• Do silt curtains and fences work and when are they required?	medium
	• What other methods control silt while dredging?	medium
stormwater management	• How does storm-water management affect water quantity and quality, sediment quantity and quality? What is the significance of dry versus wet ponds?	n/a
	• What buffer is needed to prevent sediment entry from agricultural land?	high
agricultural drains	• Can we retrofit old drain designs so that they serve their 'drainage' function without requiring ongoing maintenance?	medium
	• How effective are sediment and erosion control measures when drain maintenance work is conducted in the 'wet'?	high
materials	• Do pressure treated wood docks leach contaminants?	n/a
	• What are the effects of using anthropogenic materials in water?	n/a
dam removal	• How should dams be decommissioned to minimize effects on fish and fish habitat?	low
hydroelectric	• What are the pros and cons of different types of hydro facilities (e.g., run-of-the-river, peaking plants, etc.)?	n/a

*n/a- not available

3.4 MANAGEMENT TOOLS

This section compiles both research questions and ideas related to improving the accountability, efficiency, and consistency of approach across all areas within DFO, as well as within external agencies working to assist DFO in its fish habitat protection mandate. These improvements are needed in order for fish habitat biologists to make scientifically defensible decisions that can stand up in court. Integrating knowledge gained through science and implementing it in day-to-day activities requires a strong

link between DFO-Science and FHM. FHM requires scientific information in order to make defensible decisions in three critical stages of the file referral process. The first stage is making predictions about how a proposed work may affect fishes or fish habitat; the second stage is determining adequate mitigation and compensation measures to prevent a loss of productive capacity of habitat; and the third stage is evaluating the end product of work, mitigation, and compensation efforts. As discussed at the Science Technology Transfer Workshop (DFO 2004), up to 67% of file referral projects result in a net loss of productive capacity. Management tools that are created through applying science knowledge and risk management principles can increase the efficiency, consistency, and efficacy of file referral decisions.

Knowledge gaps and research needs have been identified regarding the management of the fish habitat provisions of the *Fisheries Act*. It was acknowledged that HAAT provides a quantitative analysis and decision-making framework from which to base HADD decisions and to plan habitat compensation efforts.

Evaluation of the effectiveness of the compensation and mitigation measures taken at a project site is key to determining whether no net loss of the productive capacity of a habitat has been achieved. In order to improve our ability to collect consistent, high quality data adequate to test whether this goal has been achieved, consistent data collection standards are required. These should apply both to data collected at a site for the purposes of project review, as well as to data collected during project monitoring. It was stressed during the workshops that data collection should be consistent with management and evaluation objectives on a per-project basis. As referral assessment tools are made available for a broader range of habitat types, it will become even more crucial to maintain data collection consistency. As habitat simulation models operate through statistical predictions based on a certain level of error being introduced by each parameter, adding uncertainty through data collection error may invalidate model predictions.

It was also noted that data collection standards and monitoring protocols need to be developed to provide adequate information on which to base FHM decisions. In order to adopt an adaptive management approach (discussed in Section 6.2), these standards and protocols need to be based on hypotheses regarding potential outcomes of mitigation and compensation plans. In the interim, several specific guideline documents were suggested to aid in file referral review. Other management goals included the development of habitat inventories to enable larger scale management plans to be created and the continued exchange of information and procedures through FHM partner agencies.

Questions and research needs relating to management tools were sorted into categories: guideline development, referral assessment tool development, cumulative impact assessment, habitat inventories, data standards, monitoring protocols, and partnerships (Table 4). These topics are discussed below. Priorities listed in the table were assigned during workshops and therefore some may be historical in nature.

Guideline Development

During the workshops, various questions were raised concerning increasing the regional consistency in how the goals of the *Fisheries Act* are implemented. These questions addressed many types of projects, including groundwater upwelling proposals, peat extraction, and aquatic vegetation removal, to name a few. The creation of guideline documents, in conjunction with DFO-Science, is an important step towards simplifying the file referral process. Guideline documents allow for a consistent approach to be taken which, if results are appropriately monitored, can provide excellent feedback into the decision-making process.

Referral Assessment Tool Development

Ideally, all science research results and information will be efficiently managed for FHM biologists through the provision of quantitative assessment tools. A prime example of the usefulness of such tools is HAAT. For shoreline works in the Great Lakes, biologists are able to provide the model with fish and habitat parameters, as well as with project information such as the amount and type of disturbance predicted. The model then makes a prediction of the loss of fishes and fish habitat based on science research and statistics. Biologists can use the model to determine adequate compensation on a project-by-project basis. Because DFO-Science can change the equations underlying the models as new information becomes available, such tools allow biologists to effectively and efficiently keep up-to-date with current research results.

Tools developed by Minns et al. (1995) have assisted FHM biologists to provide consistent reviews of habitat alteration proposals. HAAT is currently being used in lake shoreline development projects. High priority research needed on HAAT is to test how effectively it works for achieving NNL of productive capacity within the context of referral projects. Other high priority science requests included the development of similar models that can be applied to other habitat types, such as on differing substrate conditions than are currently available, or within rivers and wetlands. It was also noted that improved documentation of HAAT would enable biologists to use it more effectively.

Cumulative Impact Assessment

Referral assessment tools can also be used to coordinate cumulative impact assessment as required under the *Canadian Environmental Assessment Act.* Cumulative impact assessment is the assessment of multiple stressors on an environment, putting the potential project site within the context of other works that have, or are, occurring around that waterbody. It was agreed that development of cumulative impact assessment methods should include watershed databases that allow spatial referencing between project sites. For example, the Ontario Ministry of Natural Resources (OMNR) is developing an 'Ontario Flow Assessment Technique'. Cumulative impact assessment was thought to be particularly important for pipeline installation projects that occur over the larger landscape, and for groundwater withdrawals.

Building Habitat Inventories

The creation of habitat inventories must precede the development of habitat management plans and can also assist with habitat compensation planning. If habitat

inventories are spatially linked in a geo-referenced database, they can also assist with cumulative impact assessment. Habitat inventories provide a crucial background for the preparation of management plans. Quantifying the amounts and types of different habitats enables management decisions to consider the availability of a particular type of habitat when considering work proposals. Compensation arrangements must necessarily be adjusted for the scarcity of a habitat type as authorizations for the destruction of uncommon habitat types may require replacement with like-habitat.

In addition to quantifying the amount of various types of habitat, habitat inventories can also keep track of target areas requiring restoration. Occasionally, work requiring compensation occurs at a site with no opportunity for on-site compensation. Restoration work in identified target areas can be incorporated into compensation plans for such work sites. The development of habitat inventories was given a medium-level priority in the past; however, the recent focus on habitat mapping on the Great Lakes, coupled with its importance for making management decisions, suggests it is a high priority, especially in some areas.

Data Standards

Data standards and protocols are needed to ensure the quality of data being used to evaluate the policy objective of no net loss of productive capacity. A high priority was placed on the development of standard formats and methods for gathering, reporting, and using fish habitat information. Additionally, it was noted that these standards should enable rapid assessment of a site in order to simplify monitoring of compensation and mitigation measures.

Monitoring Protocols

High priority was given to linking monitoring protocols to evaluation procedures. All data collected through monitoring programs should be usable for testing the effectiveness of compensation requirements of a project, in order to determine if productive capacity of the habitat has been maintained. This step is key to implementing an adaptive management approach to the FHM program.

Partnerships

As the work of partner agencies is integral to the file referral process of FHM, a significant question is how to promote standard methodologies and protocols within partner agencies. Also important is the sharing of such information with proponents to enable them to collect appropriate data and plan projects. It was also suggested that some research funding may be available through partner agencies to address some of the research needs identified. For example, funding may be available from the Province of Ontario to study the effects of various buffer widths on habitat and productivity.

Additionally, several university researchers are conducting habitat research; for example, Dr. P. Chow-Fraser on wetlands (Department of Biology, McMaster University, Hamilton, ON), and Dr. E. Prepas on small streams (Faculty of Forestry and the Forest Environment, Lakehead University, Thunder Bay, ON). Work being done on habitat mapping of the Great Lakes through Environment Canada and agencies in the United States offers another opportunity to increase habitat inventories. The Ontario Ministry

of Natural Resources also has set up Fisheries Assessment Units (FAU), a network of 100+ lakes across the province, to monitor fishes and their habitat over time. This dataset can be used for experimental management to evaluate the effects of various types of development activities. A thorough review of the current and possible research interests of key agencies and universities should be conducted in order to explore the possibilities for fish habitat research opportunities and collaborations.

Table 4. Knowledge Gaps and Research Needs Concerning Management Tools

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Guideline Development		
	• Need to clarify/incorporate biodiversity guidelines/objectives into DFO habitat policy or directives.	n/a
	• Create a manual of compensation measures and habitat features by project type.	n/a
	• Develop standard mitigation measures for lakes and rivers based on Pathways of Effects models.	n/a
	• Develop guidelines regarding riparian plantings as compensation/mitigation.	high
	• Update the guideline manual on aquatic vegetation removal: include recommendations for removal techniques under different scenarios.	high
	• Develop a guideline manual on peat extraction for use by OGLA bios.	high
	• Need science-based set of guidelines on multiple uses of lakes and streams to regulate the wild rice industry until more information is known, to ensure no net loss of productive capacity.	n/a
	• Guidelines need to specify that developers provide fish habitat/species information as part of approval process.	high
	• Develop guidelines regarding the assessment by OGLA of artificial groundwater upwelling proposals.	medium
	• Need integrated guidelines to improve agricultural practices (integrate across agencies). Need to encourage shift in land use practices.	high
Referral Assessment Tool Development		
	• How effective is HAAT for achieving no net loss (does it work in practice)?	high
	• Develop manual for HAAT covering: when is it appropriate to run HAAT for a project? what about off-site compensation? when do you use condition factors in the HAAT? what do you do when habitat type does not match (e.g., sand with no cover)?	high
	• What project monitoring data should be collected to provide sufficient information to test the HAAT model?	n/a
	• Document and standardize the techniques for assessing fish habitat towards collecting consistent and comparable stream data.	high

Table 4. Knowledge Gaps and Research Needs Concerning Management Tools (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*
Cumulative Impact Assessment		
	• Need a watershed-based database to understand cumulative effects.	high
	• Identify thresholds for the acceptable number of development activities within an area or habitat type.	high
Building Habitat Inventories		
	• Develop a comprehensive management plan that maps (geo-referenced database) locations requiring rehabilitation or enhancement (could be used for testing compensation banking).	medium
	• Build habitat inventories that include management plans for various habitat types as defined by fish HSIs (Habitat Suitability Indices).	n/a
Data Standards		
	• Develop standardized format for gathering, reporting, and using fish habitat information to create a database that synthesizes information by project or habitat type and allows cumulative effects to be identified.	high
	• Need to develop more rapid assessment techniques to classify habitat using simple and efficient methods (e.g., water temperature data to determine cold/cool/warmwater habitat).	n/a
Monitoring Protocols		
	• Continue to assess previous projects and learn from these past experiences.	high
	• Need National Evaluation Program that uses standard protocols and data methods to determine both the compliance and the effectiveness of projects.	high
	• Develop protocol for information needs that are linked to a required assessment or monitoring program. Apply this model and actively evaluate its effectiveness.	high
Partnerships		
	• Integrate science and habitat management policy/priorities.	high
	• How can we promote standard methodologies within other private and government agencies?	high
	• Need to educate designers, builders, and regulators to ensure that a sufficient level of understanding of fish passage requirements is incorporated at the planning stage.	high
	• Incorporate public education and involvement into understanding and assessing cumulative impacts.	high
	• Research funding may be available for study of buffer widths for agricultural drains from province.	n/a
	• Need administrative agreements with other agencies to establish protocols on timber harvesting monitoring, etc.	high

*n/a- not available

4.0 CURRENT SCIENCE ACTIVITIES

Science research in support of FHM activities is intended to decrease uncertainty in decision making during file review and HADD determination, mitigation and compensation planning, and in monitoring the effects of a project on fishes and fish habitat. Direct DFO-Science responsibilities can be identified as research and publication of research regarding the functional and deterministic links between habitat alterations and fish communities. This mandate can be approached by reviewing available literature, re-analysis of data, or through direct experimentation. However, due to the nature of scientific research and to provide scientifically defensible answers, there will always be a time lag between the recognition and solution phase of a problem. This time lag is particularly long for research questions requiring long-term experiments. As a result, more progress has been made on some of the high priority topics that surfaced in FHM reviews in the years 1997-2000 than those listed since 2000.

DFO-Science has been active in examining research questions related to the above outlined research requirements of FHM (productive capacity, fish research, habitat research, and management tools). Progress on these topics is discussed below and includes recent research results as well as planned research, when available. A summary list of current research, by researcher, including contact information, is provided in Appendix A.

The availability of DFO-Science research results is a major issue. On one hand, results available through direct Science participation and interaction, such as at the Science Technology Transfer Workshop (DFO 2004), are relatively easy to obtain. However, indirect publications and research provide an excellent source of information that also needs to be incorporated. Difficulty incorporating such primary research may be because these results are not framed in a management context. More effort must be made to provide relevant access to information for FHM biologists. This is discussed further under recommendations (Section 6.0).

4.1 PRODUCTIVE CAPACITY

Current DFO-Science efforts have focused on the quantification of productive capacity and its functional response to changes in habitat. Productive capacity has been measured as fish density, fish biomass and, occasionally, fish community indices such as the Index of Biotic Integrity, or the Habitat Productivity Index, as well as biodiversity. Alternatively, habitat supply based fish population modelling has also been used, where productive capacity is estimated from habitat classification using physical attributes (Scruton and Clarke 2004).

In order to understand how habitat modifications affect fish habitat productivity, it is important to understand what causes natural variability in habitat productive capacity. Natural variability of fish biomass was linked tc coastal exposure in the Great Lakes (Randall et al. 2004). Coastal exposure was also a good predictor of coastal habitat characteristics and was found to influence fish distribution. Fish distribution itself may be linked to the productivity of a habitat. The research of Clarke and Scruton (2004)

found that habitat productivity may influence the spatial and movement patterns of fish. Pratt et al. (2004), in a separate study, found that fish biomass was linked to more complex habitat structure. Cott (2004) examined how habitat creation can be used to increase the productive capacity of pike habitat, suggesting that habitat creation efforts may result in an increase in the productive capacity of the habitat. In examining the functional relationship between habitat and productive capacity, fish production was found to be not linearly related to habitat alteration, suggesting that more research linking the functional response of fish production to habitat alteration is needed (DFO 2004).

Anthropogenic impacts on productive capacity have been investigated through several large-scale experiments which looked at the response of fish to major habitat alterations. Smokorowski et al. (2004) examined the effect of removing coarse woody debris from 50% of the nearshore area of three experimental lakes. They noted that the fish community response to the experimental alterations changed and developed over several years, suggesting that monitoring should be continued for as long as possible, even if it means skipping some years. Blanchfield et al. (2004) examined the effect of winter drawdown in lakes by lowering whole lake levels by 2-3 m. This study also emphasized the need for longer-term monitoring of effects, as recovery of the fish community was very slow. Mills et al. (2004) looked at the effects of aquatic vegetation removal in northern pike (*Esox lucius*) lakes. They noted that a functional association is critical to link fish decreases with habitat changes, i.e., the habitat change must be shown to affect the fish. K. Smokorowski (DFO Sault Ste Marie, ON) currently has plans to test the effects of unregulated rate-ramping on stream communities.

Progress is also being made towards understanding watershed and cumulative effects on fish habitat productivity. A threshold response was found in fish living in southern Ontario streams to the increasing imperviousness of the landscape due to urbanization within the watershed (Stanfield and Kilgour 2004). These results identify a strong link between watershed and local influences to instream productive capacity. Because habitat productivity may influence the movement patterns of fishes, Clarke and Scruton (2004) recommended including a watershed-scale analysis component during file review in order to understand the full consequences of potential development projects.

4.2 FISH RESEARCH

To date, DFO-Science activities have focused on several aspects of the fish research requirements of FHM. Minns (2004) identified that understanding the habitat requirements of all life history stages can be critical to protecting habitat productivity. As habitat requirements vary depending on life stage, when habitat supply is reduced for even one life history stage, a 'habitat bottleneck' can occur resulting in decreased fish production. Therefore, the population response is controlled by habitat supply. Cott et al. (P. Cott, DFO Yellowknife, NWT) and L. Harwood (DFO Yellowknife, NWT), in on-going studies, are characterizing fish and seal habitat use under sea ice in the Beaufort Sea (Paktoa) to understand the potential effects of off-shore drilling. Dr. W. Franzin (DFO Winnipeg, MB), along with researchers at the University of Calgary, is examining the over-wintering habitat requirements and up- and downstream movements of bull

trout (*Salvelinus confluentus)* in Alberta. Cott et al. (2005) conducted a three year study to look at the effects of winter water withdrawals. Cott also investigated pike spawning and the effects of habitat disturbance (forest fire) and habitat enhancement (testing compensation potential) on spawning success (Cott 2004; Cott et al. (Peter Cott, Fisheries and Oceans Canada, 5402 50th Ave., Suite 101 Yellowknife NWT, X1A 1E2, unpublished data)). Watershed features that influence local conditions are also important to fish populations. In his presentation at the Science Technology Transfer Workshop in Ottawa (DFO 2004), Ridgway demonstrated that a topographic index was effective for predicting the occurrence of young-of-the-year trout.

Understanding fish movement is critical to understanding fish response to barriers and engineered fish passageways, as well as to low flow conditions. Dr. W. Franzin, along with SaskPower, is undertaking IFN assessment for various Saskatchewan fishes. DFO-Regina District and Saskatchewan Environment monitored fish passage in spring 2003 in Fishing Lake in central Saskatchewan. These data will be used to build a knowledge base regarding swimming estimates through fish passageways for a variety of fish species.

Behaviourally, fish move for a variety of reasons. Clarke (DFO 2004) found that the local productivity of a habitat may influence the movement patterns of fishes. Further research on this topic is ongoing. The results may help determine whether habitat creation projects work to increase the productive capacity of a habitat, or if the new habitat is simply attracting fishes to the area.

4.3 HABITAT RESEARCH

Current fish habitat research includes some of the aforementioned studies looking at the productive capacity changes associated with whole lake or whole stream experimental modifications. Several smaller-scale studies are also being done looking at the potential effects of habitat modification on fish communities. Cott et al. (Peter Cott, Fisheries and Oceans Canada, 5402 50th Ave., Suite 101 Yellowknife NWT, X1A 1E2, unpublished data) looked at the effect of habitat disturbance (forest fire) on northern pike spawning habitat. Dr. M. Turner (DFO Winnipeg MB) is currently examining the impacts of forestry cutting practices by comparing the effects of various buffer widths on watershed hydrology, including water quality and quantity parameters.

In terms of limnological studies, Mills et al. (2004) looked at the effect of submerged plant removal on northern pike, and researchers at the Ontario Ministry of Natural Resources are examining how northern pike productivity is affected by emergent and submergent vegetation. The Alberta Conservation Association is also examining the link between shoreline development and walleye productivity. Researchers at the University of Manitoba, in conjunction with DFO, are examining the effects of wild rice farming on whole lakes and fish communities in Manitoba.

Besides the current work of K. Smokorowski on rate ramping in streams, no current DFO-Science activities are underway to look specifically at questions in the fields of fluvial geomorphology, stream ecology, or biogeochemistry. However, a joint effort

between DFO-OGLA, OMNR, the Ontario Ministry of Transportation, and CP Rail is currently being planned to study the fluvial geomorphology of stabilizing water crossings over the braided Cypress River (N. Ward, Fisheries and Oceans Canada, 100 Main St., Suite 425, Thunder Bay Ontario, P7B 6R9, pers. comm.). Bradford and Hatfield (2004) are currently developing an Instream Flow Threshold Tool to help predict the potential effects on fish communities from groundwater extraction. O'Connor et al. (2004) have been studying the effects of various low-head barrier designs on fish passage. However, many of the topics and questions regarding fish habitat may be addressed through literature reviews and the preparation of guideline documents.

4.4 MANAGEMENT TOOLS

The on-going work of FHM requires DFO-Science assistance in order to manage the risk involved with making decisions. In order to accomplish this, FHM needs objective and consistent methods and procedures (Minns 2004). Stoneman and Winfield (2004), in their presentation for the Science Technology Transfer Workshop (DFO 2004), suggest that the development of Pathways of Effects tools can assist and contribute to the consistency of file review and decision making. K. Smokorowski noted that the compensation and mitigation requirements undertaken by proponents can provide an excellent source of information (DFO 2004). Harper and Quigley (2004) recommend a National Evaluation Program that can assist with the collection and analysis of monitoring data.

Franzin et al. (2004) found that using electrofishing alone as a method to sample river fish did not lead to accurate fish abundance results, perhaps due to the complexity of river habitat. They recommend a modified sampling approach that can incorporate several types of sampling equipment, depending on habitat type. Cott and Hanna (2004) demonstrated that the setback distances and charge size recommendations outlined in the DFO explosives guidelines are ineffective to prevent loss of fishes or fish habitat. Cott et al. (2005) conducted a long-term study examining the effects of winter water withdrawal on fishes and fish habitat in order to develop guidelines that will limit the impacts on fish.

4.5 KNOWLEDGE GAPS

This report has grouped all questions into four broad categories: 1) understanding and quantifying productive capacity; 2) exploring the link between fish and their habitat; 3) identifying how works or undertakings can affect fish habitat; and, 4) developing management tools to enable fish habitat biologists to efficiently and consistently make decisions. From reviewing current DFO-Science undertakings, it appears that, although many high priority questions involve the development of consistent data standards and protocols as well as referral assessment tools, the bulk of Science efforts are towards determining the functional link between habitat and its productive capacity. Some research is being conducted to examine how fish respond to habitat modification and to understand the links between fish life history, behaviour, and habitat, but little research effort is currently being directed at management tool development.

Management tools are a means by which fish habitat biologists gain access to DFO-Science information. They can also be used to provide information and data to Science from FHM. Management tools include data collection protocols, data standards, monitoring protocols, Pathways of Effects diagrams, and referral assessment tools.

In the long run, the development of standards for file review and data collection will significantly ease the burden and cost of research by DFO-Science. Substantial efforts can be made by proponents under *Fisheries Act* authorizations to collect high quality data that will be usable to test some of these questions. DFO-Science direction is required to ensure the development of such a data collection program is in harmony with hypotheses-driven research requirements.

5.0 RESEARCH PRIORITIES

5.1 CENTRAL AND ARCTIC REGION HABITAT-SCIENCE PRIORITIES 2005

Many questions have been raised regarding the science needs and knowledge gaps of FHM. Because these questions have come out of workshops from the previous nine years, some of these questions are perhaps more historical in nature. In order to assess these lists in terms of FHM's current science needs, a short list was developed in March 2005 through interviews with members of the Regional Habitat Co-ordinating Committee and the Habitat Operations Committee. The following presents the Science priorities identified by the Regional Habitat Coordinating Committee for FHM in Central and Arctic Region. These are provided to DFO-Science to communicate FHM's need for advisory services in 2005-06. Central and Arctic priorities are listed below, specific research needs are presented in Table 5.

Central and Arctic Region Priorities:

- finalization of Regional Advisory Process for Central and Arctic Region
- species at risk (distribution, critical habitat requirements, Incidental Harm Analysis, mitigation)
- Mackenzie gas pipeline
- Risk Management Framework including Pathways of Effects, Risk Matrix and Operational Statements
- use of Habitat Alteration Assessment Tool (Ken Minns' Defensible Methods) in referral review
- Instream Flows for Fish (Methodology Development) for water taking and hydro development projects
- effectiveness of compensation / mitigation measures
- scientifically defensible monitoring programs to demonstrate the effectiveness of habitat compensation and mitigation measures
- wild rice

Table 5. Habitat-Science Priorities 2005 Central and Arctic Region- Specific Research Needs

TOPIC	QUESTIONS/NEEDS
	• What is the effectiveness of replacement habitat (e.g., pike spawning marshes, cobble/rubble placement)? • Development of a scientifically based methodology for calculating compensation ratios is needed.
Stream Crossings	• What is the effect of watercourse crossings on fluvial geomorphologic processes? • What are the cumulative effects of stream crossings? • Effective mitigation and compensation measures are needed for stream crossings. • Fish passage - investigation of culvert designs and fish swimming speeds is needed.
Hydroelectric Development and Reservoir Creation	• Impacts to fish habitat need to be defined. • Guidelines are needed for habitat biologists to use when assessing hydroelectric development proposals. • What are the appropriate compensation/mitigation measures required to achieve "No Net Loss"?
Instream Flow Needs (IFN)	• Development of quantitative assessment tools to determine IFN in streams and rivers is required. • Guidelines for the review of water taking projects are needed. What are the potential impacts of water taking projects on fish habitat under various scenarios (e g., coldwater vs. warmwater)? What information do we need to collect to assess potential impacts? • Winter instream flow needs need to be determined. • Determine in-lake flow needs- the same reasoning is involved as for instream flow needs but lakes can be a major water source and take longer to reach normal levels.
Methods for Quantifying Habitat Productivity	• "Defensible methods" need to be developed for lakes, streams, and rivers. • The development of predictive models linking productive capacity to specific habitat characteristics in lakes, streams, and rivers is needed.
Impacts of Physical Alterations on Fish Habitat Productivity	• macrophyte removal • peat extraction • deepwater wood removal
Cumulative Impacts	• There is a need for science-based management tools, models, and guidelines to address cumulative impacts of development activities on fish habitat on a watershed basis.
Surface and Groundwater Hydrology: Projects Impacting Temperature and Baseflows	• Develop new guidelines to assess projects impacting temperature and baseflows. • Guidelines should consider cumulative impacts (i.e., multiple projects in a watershed). • Research impacts of withdrawals (including water export; link to instream flow needs).
Standard Methods for Assessing and Classifying Habitats	• Develop standard assessment methods (i.e., similar to U.S. Environmental Protection Agency rapid assessment protocols) and a classification system to promote consistent habitat related data collection and assessment.
Forestry Impacts	• Block sequencing/harvest design. How much of a watershed should be harvested at one time? • Do differences in terrain matter (e.g., soil types, gradients, forest cover)? • What are the effects of road construction on muskeg and muskeg fed streams? Can they be mitigated?

Table 5. Habitat-Science Priorities 2005 Central and Arctic Region- Specific Research Needs (cont'd)

TOPIC	QUESTIONS/NEEDS
Fish Passage	• Fish speeds - update and re-analyse swimming performance data for guideline development. • Culverts - data analysis and guideline development is required. • Investigate high velocity fish screens. • Further research into fishways is needed. • Determine ways of avoiding fish mortalities.
Explosives in Waterbodies	• Studies of fish deterrents around construction and seismic activities are needed. • Further analysis of thresholds and setback distances for explosives in or near the water is required for guidelines review.
Oil and Gas	• Ocean bottom mapping and sampling in the Beaufort Sea is needed to support reviews of drilling proposals.
Kitikmeot Biomonitoring Plan	• Comprehensive habitat mapping for landscape scale development in the Kitikmeot Region of Nunavut is required.

6.0 RECOMMENDATIONS

6.1 STRATEGIES TO ADDDRESS THE SCIENCE NEEDS OF FHM

Six strategies are proposed to efficiently address the science needs of FHM while minimizing FHM dependence on DFO-Science:

- development of guideline documents
- investigation through literature reviews
- development of protocols
- science review and/or short-term research
- experimental research
- long-term research

Each of the research needs identified by Habitat Management staff, Central and Arctic Region, was assigned to one of the above strategies. A detailed list of the research needs, sorted by strategy, is provided in Appendix B.

Many of the science needs can be addressed independently by FHM using the first two strategies: 'development of guideline documents' and 'investigation through literature reviews'. Guideline documents enable FHM to provide consistent file referral decisions on topics prior to new research being conducted. Effort needs to be made to ensure that the most current versions, addressing each type of question, are available to fish habitat biologists. Research through literature reviews will determine whether a topic is an issue and how it should be addressed and would include topics requiring reviews of

FHM procedures themselves, or topics that were unlikely to be under debate in the current and recent literature.

The third strategy, 'development of protocols', requires the interaction of FHM with DFO-Science and includes the identification and description of data standards and protocols, as well as developing consensus on how productive capacity will be measured in each type of habitat. Some of these questions may involve a summary document to FHM but are unlikely to need an intensive literature review in order for DFO-Science to provide advice. Approximately one third of all the research questions fit into the above three strategies.

The remaining three strategies involve a larger input by DFO-Science. 'Science review and/or short-term research' includes questions requiring an in-depth literature review or scientific research to resolve the issue. These short-term experiments and/or literature reviews could be conducted in partnership with a graduate student project through a university. 'Experimental research' includes longer-term research projects and may be conducive to partnerships with other agencies or universities. The final category, 'long-term research', includes those questions which will require a greater investment of time for resolution.

6.2 RISK MANAGEMENT: INCORPORATING ADAPTIVE MANAGEMENT INTO THE REFERRAL PROCESS

Adaptive management is the iterative process of data collection, analysis, and adjustment of decision making strategies that enables managers to use the best available science at the same time as they progress towards answers. Adaptive management allows us to manage uncertainty in decision making (Quigley and Harper 2004). This process begins with assessment of a problem, from which a solution is derived and implemented, followed by monitoring, evaluation, adjustment, and re-analysis of the problem (Holling 1978). An example of how the adaptive management approach could work for the file referral process of FHM is illustrated in Figure 1.

Currently, FHM manages risk through its Pathways of Effects models. These diagrams model the potential for works and/or undertakings in and around water to affect fish or fish habitat. These models detail each step of the process and identify factors or conditions that can potentially lead to a HADD of fish habitat. Mitigation measures can then be identified to reduce the likelihood of a HADD. From these models, and through workshop discussions, National Operational Statements were created that list standard mitigation measures for several common types of work or undertakings (e.g., culvert maintenance, removal of aquatic vegetation, dock construction) (http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/modernizing-moderniser/epmp-pmpe/index_e.asp).

The Pathways of Effects models and the National Operational Statements both provide recommendations for mitigation measures to follow while working around water ('Recommendations' in Figure 1).

The next step in an adaptive management framework is the field testing of these mitigation measures in order to determine their effectiveness. The field testing of mitigation and compensation measures was a strong recommendation of the workshops discussed in this report.

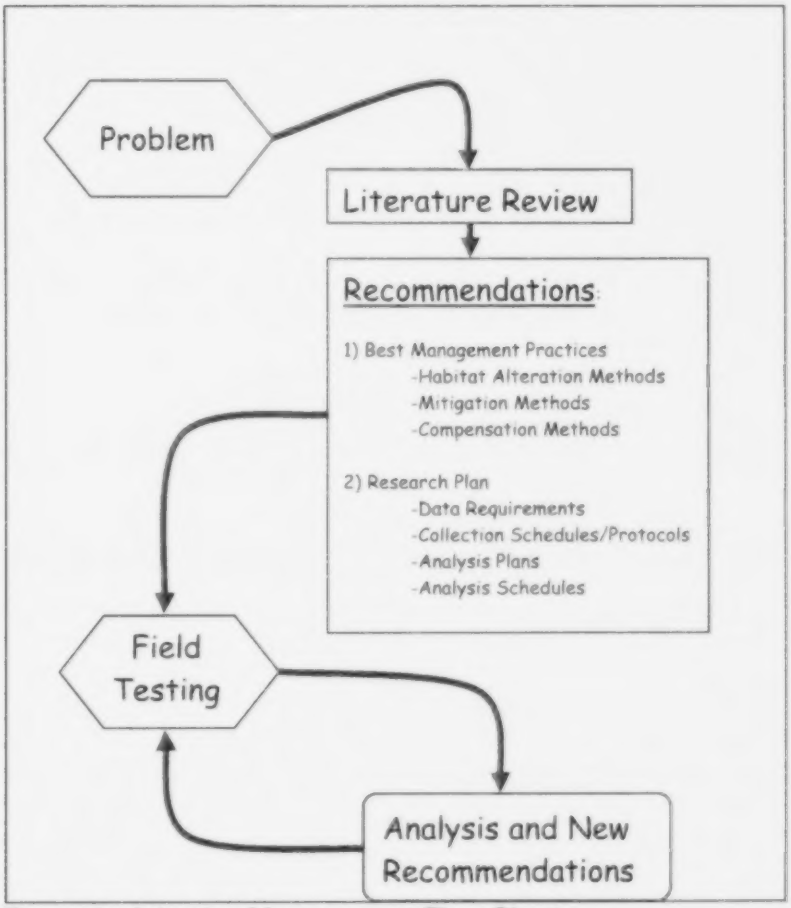

Figure 1. Adaptive Management Flow Chart.

6.3 LINKING FHM WITH DEFENSIBLE SCIENCE

Although the development of referral assessment tools was not mentioned by most fish habitat managers, the development of these tools should be given high priority within the context of each DFO-Science undertaking. Progress towards getting the answers to these many and varied questions on-hand, for day-to-day use by fish habitat managers, has been slow. For FHM biologists, referral assessment tools such as HAAT provide a quantitative and consistent method with which to make scientifically defensible decisions. These tools are needed in particular for stream habitats but also for assessing work or undertakings in smaller lakes. The use of HAAT is most appropriate

for large lakes. It is strongly recommended that DFO-Science assist FHM in the development and field testing of referral assessment tools.

7.0 CONCLUSIONS

The foregoing is a brief review of past efforts to provide direction and focus to those areas where collaboration between DFO-Science and FHM is most needed to advance the state of understanding. Through identifying research needs, classifying them by topic, and relating them to current Science activities, it becomes apparent that, in spite of the efforts that have been expended, there remain many areas where scientific investigations are needed in order to facilitate consistent application of the Policy for the Management of Fish Habitat. While the priorities are likely to differ amongst territories and provinces within the Region, some common needs emerge from this review. These are prioritized as follows:

1) Quantitative research tools are needed to assess productive capacity in a variety of aquatic ecosystems such as lakes, rivers, streams, estuaries, wetlands, and nearshore marine habitats so that greater consistency is achieved.

2) Hypothesis driven analysis is required to test and validate mitigation measures that are included in FHM Pathways of Effects models and to quantify habitat loss and gain through compensation methodologies.

3) Development of protocols to standardize the evaluation of mitigation and compensation methodologies is needed in order to enable rapid quantification of problems and allow this evaluation to feedback into further file referral decisions.

4) Development of habitat suitability models based on minimum flow and hydrologic requirements as well as swimming abilities and life histories of various fish species is crucial for the construction of referral assessment tools.

5) Development of species at risk knowledge including distribution, critical habitat requirements, and life history characteristics.

6) In order to follow up on recommendations arising out of past workshops, prepare a series of perspective papers addressing issues related to habitat productivity. Develop relevant science based guidelines to assist FHM staff.

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APPENDIX A: CURRENT RESEARCH ACTIVITIES OF DFO-SCIENCE AND AFFILIATES

Many of the following cited presentations were given at the Science Technology Transfer Workshop in Ottawa ON, Dec. 2003 (DFO 2004), and primarily represent on-going research. Other research activities have been included from various informal reports, comments on this document, and other correspondence.

Researcher	Current Activities
Alberta Conservation Association, 101 - 9 Chippewa Road Sherwood Park, AB T8A 6J7 http://www.ab-conservation.com/index.asp	• Past work includes mapping shoreline development, correlating this to walleye productivity.
Blanchfield, P. DFO, Winnipeg, MB Paul.Blanchfield@dfo-mpo.gc.ca	• Lake drawdown experiment demonstrated reduced survival and population abundance (Blanchfield et al. 2004).
Bradford, M. DFO and Cooperative Resource Management Institute, Simon Fraser University, Burnaby, BC (mbradfor@sfu.ca)	• Instream flow threshold-developing tool to help predict effects (HADD) of water extraction (Bradford and Hatfield 2004).
Casselman, J. OMNR, Peterborough, ON (613)476-3287	• Related emergent and submergent vegetation to pike productivity. Current study with Manitoba Parks and Natural Areas Branch conducting several studies to evaluate cumulative impacts on the aquatic ecosystem from recreational cottage development and associated infrastructure.
Clarke, K.D., Scruton, D.A., DFO, St. John's, NF Keith.Clarke@dfo-mpo.gc.ca	• Productivity of the habitat may influence the spatial/movement patterns of fish (awaiting further results) (Clarke and Scruton 2004).
Cott, P. DFO, Yellowknife, NWT (867) 669-4913	• Effects of forest fire on pike spawning and rearing success. Applicable scenarios where pike spawning habitat is disturbed (paper submitted). • Extensive monitoring of explosive use under waterbodies (2001-2003) demonstrated that the setback distances/charge size recommendations outlined in the DFO explosives guidelines are ineffective (Cott and Hanna 2004). • Pike habitat enhancement in the Northwest Territories with assessment of gains in productive capacity (Cott 2004). Effective compensation option. • Effects of airgun noise from river seismic exploration on fish physiology (hearing) and behaviour, Mackenzie Delta. This study has resulted in the only published information relating to the impacts of riverine seismic activities on fishes (Popper et al. 2005; other papers submitted). • Impacts of winter water withdrawal on fish in small northern lakes. Water from small lakes is used extensively for access, winter road construction, drilling, and camp use in the NWT. Results from three year study will be used to refine protocol for winter water withdrawal, a tool that guides industry in conducting work while limiting impacts to fish (Cott et al. 2005). • Characterizing fish and habitat use under sea ice in the Beaufort Sea at Paktoa (off-shore drilling target) (planned for March 2005). • Delineating instantaneous pressure change thresholds from explosives that cause harm to fish and assessing shot hole tamping techniques as mitigation to suppress pressure in water column (planned for April 2005).

APPENDIX A: CURRENT RESEARCH ACTIVITIES OF DFO-SCIENCE AND AFFILIATES (cont'd)

Researcher	Current Activities
Dick, T. University of Manitoba, Winnipeg, MB tadick@cc.umanitoba.ca	• Some work has been done in BC showing nutrient cycling in salmon streams. Dr T. Dick is studying the present habitat use by lake sturgeon below dam at Seven Sisters Falls (Winnipeg River). Oldman Dam study - monitor and determine impact of it on fish and fish habitat (planned for 2005).
Franzin, W. DFO, Winnipeg, MB William.Franzin@dfo-mpo.gc.ca	• Estimating productive capacity of streams (Franzin et al. 2004). • DFO-Calgary is working with the University of Calgary to determine bull trout movements in the Elbow River watershed, including over-wintering habitat. Saskatchewan Watershed Authority (Moose Jaw, SK) is trying to establish minimum instream flow requirement in the Upper Qu'Appelle River. Instream flow needs (IFN) assessment being conducted by SaskPower (Regina, SK) and Bill Franzin below the E.B. Campbell Dam, Saskatchewan River.
Harwood, L. DFO, Yellowknife, NWT (867) 669-4916	• Determining impacts from offshore exploratory drilling development on ringed seal reproduction and movements (year 3 of 4 year study).
Katopodis, C. DFO, Winnipeg, MB (204) 983-5181	• DFO-Regina District monitored fish passage in spring 2003. Katopodis summarizing data sources to refine swimming estimates for prairie fish species. Field studies proposed for spring 2005 to monitor fish passage.
Mandrak, N. DFO, Burlington, ON Nicholas.Mandrak@dfo-mpo.gc.ca	• On-going projects examining the clean-out and recovery of agricultural drains. • Species at risk web mapping tool development (Mandrak et al. 2004).
Mills, K. DFO, Winnipeg, MB Ken.Mills@dfo-mpo.gc.ca	• Macrophyte removal (lake) experiment demonstrated effects on fish (pike) (Mills et al. 2004).
Minns, K. DFO, Burlington, ON Ken.Minns@dfo-mpo.gc.ca	• Habitat-supply is crucial for all life stages of fish -- habitat bottlenecks occur where there is a lack of suitable habitat for specific age of fish. Population level response to habitat alteration possible and must be considered for HADD (Minns 2004).
O'Connor, L.M. DFO, Sault Ste. Marie, ON (705) 942-2848	• Sea lampreys (*Petromyzon marinus*) in the Laurentian Great Lakes: mitigating low-head barrier impacts using a modified vertical slot fishway (O'Connor et al. 2004).
Pratt, T. DFO, Sault Ste. Marie, ON Thomas.Pratt@dfo-mpo.gc.ca	• Non-linear response of fish communities to habitat alteration: what are functional responses between habitat and fish production (demonstrated biological impact not necessary for HADD determination through precedent law). • Habitat-specific production rate estimates from 5 Canadian Shield lakes (Pratt et al. 2004).
Randall, R.G. DFO, Burlington, ON Robert.Randall@dfo-mpo.gc.ca	• Productive capacity of lake shorelines varies with fetch. Useful in mapping and estimating productive capacity of lakes (Randall et al. 2004).
Ridgway, M. OMNR, Peterborough, ON (705)755-1550	• Feeder-stream and very small lakes crucial to cold-water trout habitat (age 0). Topographic Index predicted the occurrence of trout (DFO 2004).

APPENDIX A: CURRENT RESEARCH ACTIVITIES OF DFO-SCIENCE AND AFFILIATES (cont'd)

Researcher	Current Activities
Scruton, D.A. DFO, St. John's, NL	• Generalizations about habitat use are bounded with uncertainty. Currently looking into researching how habitat supply influences productive capacity (Scruton and Clarke 2004).
Smokorowski, K.E. DFO, Sault Ste. Marie, ON Karen.Smokorowski@dfo-mpo.gc.ca	• Fisheries and Oceans Canada, Ontario Ministry of Natural Resources, and Brascan Power Corporation Limited are collaborating on a long-term, Adaptive Environmental Assessment and Management experiment, to test whether regulating the rate of change of water flow (or ramping rates, $m^3 \cdot s^{-1} \cdot h^{-1}$) through hydro dam turbines can provide a more favourable environment for fish, while allowing energy production to be maximized (planned for 2005). • Experiment on littoral zone wood removal in lakes. Found 50% removal of lake wood does not represent a HADD (Smokorowski et al. 2004).
Stanfield, L. OMNR, Picton, ON Les.Stanfield@MNR.gov.on.ca	• Bioregional model for predicting thresholds of change for tributaries - threshold response to imperviousness quantified for southern Ontario (Stanfield and Kilgour 2004).
Steedman, R., OMNR, Thunder Bay, ON	• Research on buffers for foresty practices (on-going).
Turner, M. DFO, Winnipeg, MB (204) 983-5215	• Proposal by Dr. Michael Turner to examine the impacts of forestry cutting practices on various water quality and quantity parameters on a watershed basis, as a function of varying riparian buffer widths in the boreal forest. Study on the impact of fire and anthropogenic disturbances by forestry development on hydrology (2004 project).
University of Manitoba Winnipeg, MB	• Position paper on wild rice is being developed by DFO-Dauphin District. • Graduate work is underway on lakes in Manitoba, in collaboration with DFO.

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APPENDIX A: CURRENT RESEARCH ACTIVITIES OF DFO-SCIENCE AND AFFILIATES (cont'd)

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APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGIONS, FISHERIES AND OCEANS CANADA

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Guideline Documents			
policy	• Integrate science and habitat management policy/priorities.	high	
species at risk	• Need to clarify/incorporate biodiversity guidelines/objectives into DFO habitat policy and directives.	n/a	
Testing: compensation benefits	• Need mechanism to ensure that compensation benefits are realized.	high	
Testing: mitigation	• Need appropriate monitoring to test mitigation recommendations and Best Management Practices (BMPs).	high	
Mackenzie Gas Pipeline	• Need to include corridor-style projects in this category because of their far-reaching effects (e.g., pipeline).	high	
whole lake destruction	• Develop an explicit decision framework for determining if the loss of a lake can be compensated to the extent that no net loss is achievable. Need to have other options available if we cannot achieve no net loss (NNL) through standard compensation measures for a particular site. Do we need an additional entry into the hierarchy of preferences for achieving no net loss of habitat?	high	
agricultural drains	• Research funding may be available for study of buffer widths for agricultural drains from province.	n/a	
wild rice	• Need policy on multiple uses of lakes and streams (wild rice and commercial/recreational fishing).	n/a	
Assessing: agriculture	• Need integrated guidelines to improve agricultural practices (integrate across agencies). Need to encourage shift in land use practices.	high	
Assessing: vegetation removal	• Update the guideline manual on aquatic vegetation removal: include recommendations for removal techniques under different scenarios.	high	
Assessing: culverts and bridges	• Guidelines needed to make it mandatory for developers to provide fish habitat/species information as part of approval process.	high	
	• Need to document requirements for fish screens on intakes used when building ice roads/bridges.	n/a	
	• Need guidelines to determine when open bottom culverts are required.	high	
	• Need guidelines on assessing the risk of sedimentation in the review of culvert projects.	medium	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Guideline Documents (cont'd)			
Assessing: groundwater upwellings	• Develop guidelines regarding the assessment by Ontario-Great Lakes Area (OGLA) of artificial upwelling proposals.	medium	
Assessing: cumulative effects	• Need guideline document to identify and respond to cumulative effects, including clarifying pertinent data needs.	high	
compensation planning	• Create a manual of compensation measures and habitat features by project type.	n/a	
	• Document and standardize the techniques for assessing fish habitat (refer to *Stream Assessment Protocol for Southern Ontario* (Stanfield et al. 2001)) to collect consistent and comparable stream data.	high	
	• Develop guidelines regarding riparian plantings as compensation and/or mitigation.	high	
	• Create management plans for sites and locations requiring rehabilitation or enhancement in order to determine target areas and project types for habitat restoration/creation and habitat classification (hi-med-low sensitivity) to be used for compensation banking.	n/a	
Fish Habitat Management (FHM) Literature Review			
Testing: compensation	• Review OGLA projects to determine effectiveness of mitigation and compensation measures on maintaining productive capacity.	high	
	• Examine fish attraction, avoidance and guidance at dams and irrigation project canals.	high	
Testing: mitigation	• Assessment of individual BMPs and suite of BMPs to determine if water quality is improved and techniques are economically viable.	n/a	
	• Review the long-term success of baffled culverts (tendency to infill with debris).	n/a	
	• How does natural versus artificial substrate within culverts affect fish passage? The cumulative impacts including fluvial hydrology and forest management plans need to be considered.	n/a	
	• Do silt curtains work and when are they required?	medium	
	• Where, and under what conditions, do silt fences work? How much control of silt, using silt fences, is enough? (The Ontario Ministry of Transportation is currently studying this topic).	n/a	
	• Do other techniques work to determine the net change in fish habitat (e.g., aerial videos)?	high	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
FHM Literature Review (cont'd)			
instream flow	• What is required to develop a better understanding of the impacts from mining activities on fish habitat- effect on base flows in nearby streams, effect on water temperatures, effects on groundwater flow and quality (including impacts of operations below the water table)?	high	
	• What are the pros and cons of different types of hydro facilities and their effects on flows and habitat (e.g., run-of-the-river, peaking plants, etc.)?	low	
whole lake destruction	• Can we achieve NNL in pristine areas? Conduct research on the feasibility of various compensation measures in adjacent undisturbed environments (creation of spawning marshes, shoals).	high	
	• How should dams be decommissioned to minimize effects on fish and fish habitat?	low	
Habitat Suitability Indices	• How do we assess impacts of causeways on fish migration?	low	
	• What are effective techniques that can be used in culverts to ensure fish passage?	high	O'Connor et al. 2004
	• What are sustained and burst swimming speeds for non-salmonid and larval fish?	high	Katopodis, Chris DFO, Winnipeg, MB (204)983-5181; Walks, D.J. (DFO, Burlington, ON)
Assessing: submarine cables	• Do submarine cables affect the aquatic environment with respect to lead, copper, oils, magnetic fields, and physical disturbance?	n/a	
Planning: compensation	• Are floating docks and pole docks harmful?	n/a	
	• Do pressure treated wood docks leach contaminants?	n/a	
	• What are the effects of using anthropogenic materials in water?	n/a	
	• What are the best designs to minimise impacts of waves and ice on a structure/boat that improves fish habitat?	n/a	
	• Does the PEI bridge abutment design improve fish habitat? Would this design function similarly in freshwater?	n/a	
	• How can erosion problems resulting from improper culvert positioning be remediated?	medium	
	• What designs minimize road sediment washing into fish habitat?	n/a	
	• What are the impacts of primary, secondary, and tertiary road development? How do abandoned roads affect fish habitat as the roadbeds decay?	n/a	
	• Is there a design available for self-sustaining groundwater upwellings that requires little maintenance?	medium	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
FHM Literature Review (cont'd)			
Planning: Compensation (cont'd)	• What techniques are effective in the design of wetland projects? What requirements should OGLA have in wetland creation projects to ensure the enhancement of fish habitat?	medium	
	• How does stormwater management affect water quantity and quality, sediment quantity and quality? What is the significance of dry versus wet ponds?	n/a	
Science Assistance to Develop Protocols			
Testing: compensation	• How should artificial shoal creation projects be effectively monitored?	medium	
	• Which compensation measures and how much should be used per project? Develop standard protocols for determining adequate compensation (this gets back to defensible methods for all habitat types/projects).	high	
	• Develop manual for Habitat Alteration Assessment Tool (HAAT), also known as Defensible Methods (Minns et al. 1995) covering: when is it appropriate to run a habitat suitability matrix (HSM) (Minns et al. 2001) method for a project, what about off-site compensation, when do you use condition factors in HAAT, what do you do when habitat type does not match (e.g., sand with no cover).	high	
	• Do OGLA project monitoring data provide sufficient information to test HAAT model?	n/a	
	• Use compensation agreements effectively to learn from past projects (e.g., establish consistent monitoring programs).	high	
Testing: mitigation	• Standardize monitoring efforts in order to test the effectiveness of mitigation measures.	n/a	
	• Test mitigation measures in National Operation Statement on Culvert and Bridge Maintenance (http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/modernizing-moderniser/epmp-pmpe/index_e.asp)	n/a	
instream flows	• What are the most appropriate instream assessment methods to use under different scenarios? Clear direction on how to use each method is needed. Scenarios would be dependent on project type (e.g., water taking/mining/pond construction) and habitat type (coldwater/warmwater).	high	
lake/reservoir destruction	• Need to evaluate past and future compensation agreements for this to inform future projects. Develop protocols that describe information requirements to assess productivity.	high	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Science Assistance to Develop Protocols (cont'd)			
agricultural drains	• How can we maintain or increase the productive capacity of existing municipal drains that are subject to ongoing maintenance?	medium	
	• What type of compensation is appropriate for intermittent drains?	low	
wild rice	• Need science-based set of guidelines to regulate the industry until more information is known to ensure NNL.	n/a	
Assessing: vegetation removal	• When, where, and how does the removal of <100m^2 of aquatic plants affect the productive capacity of a waterbody?	high	
Assessing: wood removal	• Is 5m appropriate for determining shallow versus deep?	high	
Assessing: cumulative effects	• Develop a framework for conducting cumulative impact assessment for rivers and/or watersheds: how can DFO document cumulative impacts?	n/a	
	• How do we set limits for the acceptable number of development activities within an area?	high	
Science Review and/or Short-Term Research			
species at risk	• What are habitat requirements for species at risk (e.g., in the Arctic: freshwater fourhorn sculpin (*Myoxocephalus quadricornis*), Bering wolffish (*Anarhichas orientalis*))?	high	
Testing: compensation	• Do constructed structures increase or re-distribute productivity?	n/a	Pratt et al. 2004; Clarke and Scruton 2004; Cott 2004
	• Need to develop more rapid assessment techniques to classify habitat using simple and efficient methods (e.g., water temperature data to determine cold/warmwater habitat) that can be implemented by the proponent during pre-post construction. This would help quantify the effectiveness of compensation-mitigation measures.	n/a	
	• What is the effect of side-casting material and the resulting creation of bermed or island areas? Do these types of habitat creation structures increase the productive capacity of the habitat?	high	
	• How effective are artificial shoals for increasing productivity of various species?	medium	
	• Do root wad or tree crown additions help to increase the productive capacity of fish habitat? Are they effective compensation? When do they fail?	medium	
	• Are artificial spawning sites successful? How long do they last? What monitoring should be done?	low	
	• What percentage of the created wetland survives and for how long?	medium	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Science Review and/or Short-Term Research (cont'd)			
Testing: mitigation	• How effective are the methodologies for mitigation that are being promoted? What do past projects tell us?	medium	
	• Do mitigation techniques address the requirement of all life history stages (e.g., over-wintering habitat in streams)?	n/a	
	• Do some designs work better than others for increasing the productive capacity along with providing shoreline protection?	n/a	
	• Clarify how effective culvert baffles are at aiding fish passage as well as describe types of baffle design that are most appropriate.	high	
	• What are the implications of culvert size and design to fish migration and passage?	high	
	• What is the appropriate culvert invert depth (10, 20, 25%) under various substrate conditions (clay, gravel, sand)?	high	
	• Are culverts that have been installed in Ontario effective in passing fish? What are the impacts to the upstream and downstream habitat of culverts that obstruct fish passage?	high	
	• How do buffer strip width requirements vary with sediment, nutrients, temperature, allochthonous inputs, slope, and soils? How much forest can be cut before you reach a threshold and see a hydrological effect? (e.g., 100' buffer strip around a lake trout lake is not defensible, 50' buffer strip around a warmwater community is not defensible).	n/a	
instream flows	• Predicting flow discharges in prairie streams - current inaccuracies of +/-20% make design of crossings difficult to ensure fish passage is achieved.	n/a	
	• What types of restrictions are needed in operational plans of hydroelectric facilities to protect fish habitat from fluctuating water levels?	high	Smokorowski , K.E. DFO, Sault Ste. Marie, ON Karen.Smokorowski@dfo-mpo.gc.ca (planned)
	• Instream flow needs (IFN) - need to assess fish habitat activities and requirements during winter months in prairie streams and watercourses where winter conditions are restrictive due to minimal water flows/levels.	n/a	Cott et al. 2005; Franzin, William DFO, Winnipeg, MB William.Franzin@dfo-mpo.gc.ca (planned); DFO-U. of Calgary
	• How are shallow water ground water systems and base flows in nearby streams connected?	n/a	
Mackenzie Gas Pipeline	• What are the effects of pipeline installations on habitat?	n/a	
	• What are typical channel forms in bedrock and permafrost dominated systems? How do these systems respond to changes in sediment load, flows, etc.?	high	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Science Review and/or Short-Term Research (cont'd)			
whole lake destruction	• Whole lake losses: How do they get quantified? What are the critical habitat parameters that need to be measured? What compensation measures would be appropriate to make up for these losses? What compensation measures have been undertaken in the past and how successful have they been?	high	
Habitat Suitability Indices	• What are the impacts to fish and fish migration associated with hydroelectric, flood control, carp barriers, and lamprey barriers?	n/a	Dick, T. University of Manitoba, Winnipeg, MB tadick@cc.umanitoba.ca ; O'Connor et al. 2004
	• What is the role of wetlands in fish community dynamics?	n/a	
	• What are the effects of adding habitat features?	n/a	Randall et al. 2004
	• How does woody debris contribute to fish habitat structure?	n/a	
	• Quantify the impacts of shoreline development on either fishery productivity or fish life history.	n/a	Alberta Conservation Association http://www.ab-conservation.com/index.asp
	• Do new habitat structures contribute to fish production or redistribute it?	high	
	• Fish passage for pike: required to ensure current data on pike swimming abilities are accurate, so that design of road crossings, specifically culverts, enables pike to access spawning habitat upstream of road crossings during spring migrations. Is the 3Q10 appropriate given the timing of spawning runs for walleye, pike, and sucker in the Prairies?	n/a	Katopodis, Chris DFO, Winnipeg, MB (204) 983-5181
	• How long can a culvert be before darkness becomes a barrier or impediment to fish movement?	high	
	• Natural Stream Channel culverts - are these structures a HADD or do they have the same productive capacity as the natural stream?	n/a	
	• Fish egg densities - information is needed to quantify fish egg density as low, medium, or high.	n/a	
	• Refine Habitat Suitability Indices (HSI) for keystone fish species in the Prairies	n/a	U.S. Fish and Wildlife Service http://www.nwrc.usgs.gov/wdb/pub/hsi/hsiintro.htm ; or, http://el.erdc.usace.army.mil/emrrp/emris/emrishelp3/list_of_habitat_suitability_index_hsi_models_pac.htm

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Science Review and/or Short-Term Research (cont'd)			
Habitat Suitability Indices (cont'd)	• What are successful methods for creating new spawning sites for various fish species?	low	Cott 2004 (pike); Cott (paper submitted) - effects of forest fire on pike spawning and rearing success.
	• Is there a difference in how fish use various building materials (e.g., steel vs. cedar logs, cribbing vs. stone, etc.)?	n/a	
	• Are artificial groundwater upwelling areas successful in promoting fish spawning?	medium	
	• Do artificial upwellings work and are they self-sustaining?	n/a	
agricultural drains	• What is appropriate compensation for drains requiring authorizations?	high	
	• How are agricultural drains used by fish as habitat?	n/a	
	• Do classification methods accurately depict the true fish community and in particular fish that use drains seasonally?	high	
	• Can agricultural drains be economically designed to better emulate natural channels?	high	
	• How effective are sediment and erosion control measures when work is conducted in the 'wet'?	high	
American Eel	• How do barriers, especially with regard to hydroelectric development, etc., affect movement of eels?	high	
Assessing: vegetation removal	• How does fragmenting ('cookie cutting') a weed bed or cattail mat affect habitat productivity?	n/a	
	• Do artificial channels cut through dense cattail (monoculture) increase the productive capacity of fish habitat? This technique is currently being used as a suggested compensation measure, but no scientific studies have been undertaken.	medium	
	• What is the life span of artificial channels cut through cattails?	medium	
	• What buffer is needed to prevent sediment entry from agricultural land?	high	
Assessing: aquaculture	• What are the effects of aquaculture/fish cage culture?	n/a	
Assessing: dock construction	• Should there be a size restriction on the surface area of decking used for docks and boathouses? Should this vary with substrate type?	low	
	• How should docks/steel walls be designed to maximize fish habitat as well as maintaining their function?	low	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Science Review and/or Short-Term Research (cont'd)			
Assessing: culverts and bridges	• How does the partial damming associated with raised fords (crossing structures that are elevated above base flow- using culverts- but below high flow) affect riparian vegetation, sediment input, water velocity?	n/a	
	• What are the indirect and cumulative impacts from encroachment, bridges, swales, and culverts?	n/a	Stanfield and Kilgour 2004
	• Are there any effects of ice roads?	n/a	
Assessing: off-shore drilling	• Determine impacts from off-shore drilling on fish and fish habitat.	high	Cott (planned March 2005)- characterizing fish and habitat use under sea ice at Paktoa (Beaufort Sea)
Assessing: explosives	• Test if setback distances and charge size recommendations are effective.	high	Cott and Hanna 2004; Popper et al. 2005- effects of airgun noise from river seismic exploration on fish physiology (hearing) and behaviour, Mackenzie Delta; Cott (planned April 2005)- delineating instantaneous pressure change thresholds from explosives that cause harm to fish and assessing shot hole tamping techniques.
Assessing: shoreline works	• What are the impacts of beach creation on habitat?	n/a	
	• Do breakwalls with built-in overhangs increase productive capacity?	n/a	
Assessing: peat extraction	• What are the effects of peat extraction activities on fish resources (including fish habitat)?	high	
Assessing: heat loops	• What are the impacts of heat exchange loops?	n/a	
Assessing: woody debris	• What is the effect of beaver dam removal on habitat?	n/a	
	• Does the removal of naturally occurring woody debris from littoral areas differ from the removal of artificial debris (e.g., scrap wood)?	low	
	• What impacts to water quality result from log removal in terms of sediment disturbance, DO, and water chemistry?	high	Smokorowski et al. 2004

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Science Review and/or Short-Term Research (cont'd)			
Assessing: wetlands	• Need to understand the role of wetlands for habitat - what are the effects of removing 100 m^2 of wetland? How does substrate influence the effects of wetland removal?	n/a	
	• What is the impact on lakes of wetland conversion into marinas?	n/a	
	• What is the impact of wetland restoration works on contribution of the project site to fishery production? Are wetland restoration projects different than on-line ponds? How do their associated water level control structures affect access to spawning areas for pike, muskie, or migratory salmon?	n/a	
Experimental Research			
Testing: compensation	• Do riparian plantings adequately compensate for loss of productive capacity of fish habitat?	high	Turner, M. DFO, Winnipeg, MB (204) 983-5215
	• Do riparian plant species affect the productive capacity of the adjacent waterbody?	high	
	• How effective is wetland creation towards increasing the productive capacity of a habitat?	medium	
Testing: mitigation	• Does natural channel design maintain the productive capacity of the stream?	n/a	DFO, Burlington, ON
instream flows	• What are the impacts of (artificial) water level fluctuations and rate ramping (where increased diversion of river water to turbines can cause 2 m change in water level within 1 day) on fish populations and fish habitat? How do we use this information in referral file review?	high	Smokorowski, K.E., DFO, Sault Ste. Marie, ON Karen.Smokorowski@dfo-mpo.gc.ca (planned 2005)
	• What are the effects of water levels on fish spawning success and fish communities in general? Is this effect similar to that found for reservoirs (synthesize with a literature review)?	n/a	Blanchfield et al. 2004
	• Examine behavioural responses to hydraulic conditions and changing water levels for various species of fish and various life stages.	high	
	• How does aggregate operation affect base flows?	n/a	
pipeline installation	• Difficult to predict where sediment will be deposited during installation. Short and long term effects are unknown.	high	
lake destruction	• Quantify the effects of lake destruction and dam removal on fish and fish habitat.	high	
agricultural drains	• After drain cleanout, what is the recovery timing for various species?	high	
	• How do drains and intermittent watercourses contribute to downstream productive capacity?	high	

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Experimental Research (cont'd)			
wild rice	• Need more detailed/accurate information to know the potential impact of introduced wild rice to lake habitat.	n/a	DFO - Univ. of Manitoba graduate student
Assessing: shoreline changes	• How productive are intertidal zones in northern climates and how do they support the local fisheries?	high	
Assessing: vegetation removal	• What are the effects associated with removal of emergent/ submergent vegetation? Are there areas or substrates where vegetation is more valuable? What is the 'critical limiting' habitat? What patch size or quantity of aquatic vegetation is important for fish?	n/a	Mills et al. 2004; Casselman, John OMNR, Peterborough, ON (613) 476-3287 (on-going)
Assessing: wood removal	• What are the effects of log salvage operations and/or nearshore woody cover removal on the productive capacity of aquatic ecosystems?	high	Smokorowski et al. 2004
	• Is the effect of the wood removal on productivity dependant on the amount of wood and the quality of wood present (e.g., several logs versus 100 m^2 of scrap wood)	low	Smokorowski et al. 2004
	• What is the value as fish habitat of the wood that is being removed in lake areas >5 m deep?	low	
Long Term Research			
species at risk	• How does aquatic biodiversity relate to the preservation of healthy fish habitat and its productive capacity?	high	
Testing: compensation	• Fine-tune HAAT- does it work in practice?	high	
	• Is compensation/mitigation working? Is productive capacity being improved? Is the information we are collecting sufficient to assess the effectiveness of compensation/ mitigation measures? If not, what should we be collecting?	n/a	
Testing: mitigation	• Are mitigation techniques (e.g., Pathways of Effects, National Operational Statements) working to maintain or increase productive capacity of fish habitat?	n/a	
	• Can we model/predict riparian buffer widths from defined parameters?	high	
	• Riparian protection needs -determine necessary setback distances in prairie and boreal streams to protect shoreline habitat. Consistency with provincial guidelines in AB, SK, and MB would be helpful.	high	Turner, M. DFO, Winnipeg, MB (204) 983-5215 2004
	• How important are riparian buffers to aquatic ecosystem productive capacity? How much are we actually contributing towards compensation for the loss of productive capacity of fish habitat when requesting riparian plantings, and how does this change in lakes versus rivers?	n/a	Turner, M. DFO, Winnipeg, MB (204) 983-5215 2004

APPENDIX B: RESEARCH NEEDS IDENTIFIED BY HABITAT MANAGEMENT STAFF IN CENTRAL AND ARCTIC REGION, FISHERIES AND OCEANS CANADA (cont'd)

TOPIC	QUESTIONS/NEEDS	PRIORITY*	CURRENT ACTIVITIES
Long Term Research (cont'd)			
instream flow	• What level of base flow is needed to support fish habitat?	high	Bradford and Hatfield 2004
	• What are the cumulative impacts of surface and groundwater withdrawals on fish and fish habitat from a watershed perspective?	high	
	• Does IFN assessment work to prevent net loss of productivity?	high	Bradford and Hatfield 2004
lake destruction	• Need to be able to quantify productive capacity of a whole lake with respect to loss of a lake or creation of a lake.	high	
	• What are the impacts of whole lake destruction from mining activity?	n/a	
agricultural drains	• What is the contribution or importance of intermittent drains/ditches to fish habitat? How does closing in of these drains impact the habitat?	high	
Assessing: cumulative effects	• Need to have research with particular emphasis on how micro changes affect macro changes in watersheds. Can the overall impact be qualified/quantified with synergistic effects?	high	
	• When do incremental shoreline alterations become measurable with respect to filling, loss of shallow water habitat, impacts of dock, boathouses, breakwaters, shoreline currents?	n/a	
	• What are the cumulative impacts of dredging projects, in particular during conditions of low water?	medium	
	• What are the effects of infilling or dredging wetlands?	n/a	
	• How much aquatic vegetation can be removed from eutrophic (prairie) lake systems before HADD occurs?	n/a	Mills et al. 2004; Casselman, John OMNR, Peterborough, ON (613) 476-3287 (on-going); Alberta Conservation Association http://www.ab-conservation.com/index.asp
Assessing: timber harvesting	• What are the effects of timber harvest on fish production?	high	Turner, M. DFO, Winnipeg, MB (204) 983-5215 2004
Assessing: mine de-commissioning	• How does mine de-commissioning affect habitat? This is a largely unexplored issue.	n/a	
Long Term Research Goal			
productive capacity	• Quantify gains and losses of productive capacity of fish habitat through understanding the functional relationship between habitat and fish production.	high	Minns 2004; Pratt et al. 2004; Smokorowski et al. 2004

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